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## EC01-156 Sugarbeet Production Guide

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# *Sugarbeet* Production Guide



***Published by the***  
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***In cooperation with***  
Colorado State University  
Montana State University  
University of Wyoming  
USDA Agricultural Research Service

***Coordinated by the***  
Central High Plains Dry Bean and Beet Group







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# Table of Contents

<b>Acknowledgments</b> .....	vi
<b>Authors</b> .....	vii
<b>Chapter 1</b>	
<b>Introduction</b> .....	1
<b>Chapter 2</b>	
<b>Growing Sugarbeet to Maximize Sucrose Yield</b> .....	3
The Importance of Photosynthesis .....	3
Seasonal Variation in Sunlight .....	3
Growth Stages .....	3
Maximizing Sucrose Yield .....	7
<b>Chapter 3</b>	
<b>Seed and Varieties</b> .....	9
Seed and Germination Process .....	9
Seed Germination and Relationship with Field Emergence .....	10
Steps in Processing Sugarbeet Seed .....	12
Seed Processing .....	13
Influence of Seed Size on Field Emergence .....	13
Pesticides Applied to the Seed .....	14
Seed Steeping and Priming .....	14
Seed Storage .....	15
Types of Sugarbeet .....	15
Variety Approval Process .....	17
Pest Resistance .....	18
Where to Get and How to Use Variety Performance Information .....	19
Sugarbeet Contract Specifications .....	20
Relationship of Crop Quality to Factory Performance .....	20
<b>Chapter 4</b>	
<b>Crop Rotation</b> .....	21
<b>Chapter 5</b>	
<b>Tillage and Seedbed Preparation</b> .....	23
Purposes for Tillage .....	23
Tillage Considerations: Less is Better – Utilize Mother Nature .....	28
Successful Tillage Systems .....	29
Tillage Tracks and Tractor Tire Tracks .....	31
<b>Chapter 6</b>	
<b>Wind Erosion Control</b> .....	37
The Erosion Process .....	37
Reducing Wind Erosion .....	37
Crop Residues .....	38
Cover Crops .....	39

## Chapter 7

<b>Planting</b>	43
Planting Date	43
Replanting	47
Row Width	48
Plant Population	51
Plant-to-Stand vs Thinning – What Seed Spacing?	52
Depth of Planting	53
Sugarbeet Planters	56
Seedbed	57
Seed Coating	57
Field Speed	58
Planter Maintenance	60
Static Calibration for MaxEmerge with Pneumatic Metering Unit	60
How to Calibrate a Planter for Sugarbeet	61
Planter Test Stand	62
General Purpose “Corn” Planter or Precision Sugarbeet Planter?	63
Planter Adaptability	64
Seed Monitor	64
Seed Firming Wheel or Devices	64
Row Firming or Cleaning Accessories	64
Pneumatic vs Mechanical Seed Metering	65
Furrow Opener	66
Press Wheels	67
Tips for Popular Planters	68
How to Measure Actual Plant Population and Percent Field Emergence	73

## Chapter 8

<b>Fertilizing Sugarbeet</b>	75
Soil Testing	75
Nitrogen Recommendations	75
Phosphorus Recommendations	78
Potassium Recommendations	79
Micronutrient Recommendations	80

## Chapter 9

<b>Insect Management</b>	81
Seed/Seedling Attacking Insects	81
Foliage Feeding Insects	90
Root Feeding Insects	102
Sugarbeet Root Maggot Trap Construction and Placement	110
Insecticide Application	114
Managing Insecticide Resistance	116

## Chapter 10

<b>Weed Control</b>	117
Weed Competition	118
Recommended Publications on Weed Management	117
Planning a Weed Management Program	119
Weed Seedlings Common to Sugarbeet	120
Herbicide Tolerant Sugarbeet	129
Herbicide Resistance	129
Strategies to Minimize Herbicide Resistant Weeds	130
Crop Injury from Herbicides	130



## Chapter 11

<b>Disease Management</b> .....	131
Diseases Caused by Viruses .....	131
Diseases Caused by Bacteria .....	138
Diseases Caused by Fungi Affecting Roots .....	139
Diseases Caused by Fungi Affecting Foliage .....	148
Wilt Diseases .....	152
Diseases Caused by Nematodes .....	153

## Chapter 12

<b>Irrigation Management</b> .....	161
Goal of Irrigation .....	161
Soil Water Characteristics .....	161
Sugarbeet Plant Characteristics .....	164
Sugarbeet Water Use .....	165
Early Season Water Management .....	166
Late Season Water Management .....	166
Irrigating for Germination and Emergence .....	167
Furrow Irrigation Water Management .....	170
Sprinkler Irrigation Water Management .....	174
Water Management Impact on Disease .....	177
Scheduling Irrigation .....	178

## Chapter 13

<b>Sugarbeet Harvest</b> .....	179
Preparation of the Field in Anticipation of Harvest .....	179
Maturity of the Crop .....	181
When to Harvest .....	182
Defoliation and Scalping .....	182
Digging and Handling .....	183
Estimating Field Loss .....	184
Root Damage .....	185
Field Loss .....	185
Soil Damage Affecting Following Crops .....	186
Tare Disposal .....	187
Custom Harvest .....	187
Safety .....	188

## Chapter 14

<b>Economics of Sugarbeet Production</b> .....	189
Cost of Production Budgets .....	189
Process for Changing the Budget from a Defined Operation to a Custom Operation .....	190
Evaluation of Production Cost Categories .....	194
Partial Budgets for Decision Making .....	195

## Chapter 15

<b>Scouting Calendar and Injury Diagnostic Guide</b> .....	197
Sugarbeet Scouting Calendar .....	198
Sugarbeet Injury Diagnostic Guide .....	200

## Chapter 16

<b>Glossary</b> .....	203
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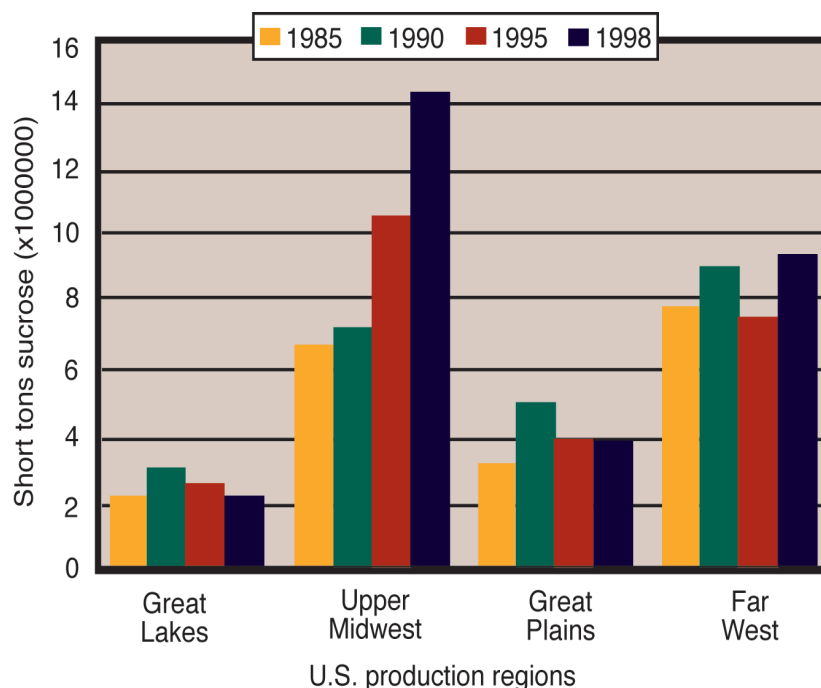


*By Robert G. Wilson*

Sugarbeet and sugarcane are the major sources of sucrose, a sweetener in a vast range of foods. Total world production of sucrose was estimated at 126,500 metric tons in 1998-1999 of which 37 percent was from sugarbeet and 63 percent was from sugarcane. Since its origin in central Europe in 1802, sugar production from sugarbeet has spread around the world. Sugarbeet was introduced in the United States with the first successful processing plant built in California in 1870. The California plant was followed by factories in Nebraska and Utah.

Sugarbeet factories were constructed in Nebraska at Scottsbluff and Bayard in 1910 and 1917, respectively; in Colorado at Greeley and Fort Morgan in 1902 and 1906, respectively; in Wyoming at Lovell, Torrington and Worland in 1916, 1923 and 1917, respectively; and in Montana at Billings and Sidney in 1906 and 1925, respectively. By 1930 the general pattern of the domestic sugarbeet industry as we know it today had been established with crop production in California, Colorado, Idaho, Michigan, Minnesota, Montana, Nebraska, North Dakota, Oregon, Texas, Washington, and Wyoming.

Each year Colorado, Montana, Nebraska and Wyoming produce about 4.5 million to 6.0 million tons of sucrose. This accounts for about 14 percent to 22 percent of U.S. sucrose production from sugarbeet (*Figure 1.1*). Sugarbeet has been an important agricultural crop in this region for the last century. In Nebraska alone it is estimated that the 74,000 acres of sugarbeet grown each year contribute \$60,000,000 to the local economy. Sugarbeet grown in the Great Plains region are processed by Western Sugar (six factories) and Impe-



**Figure 1.1**

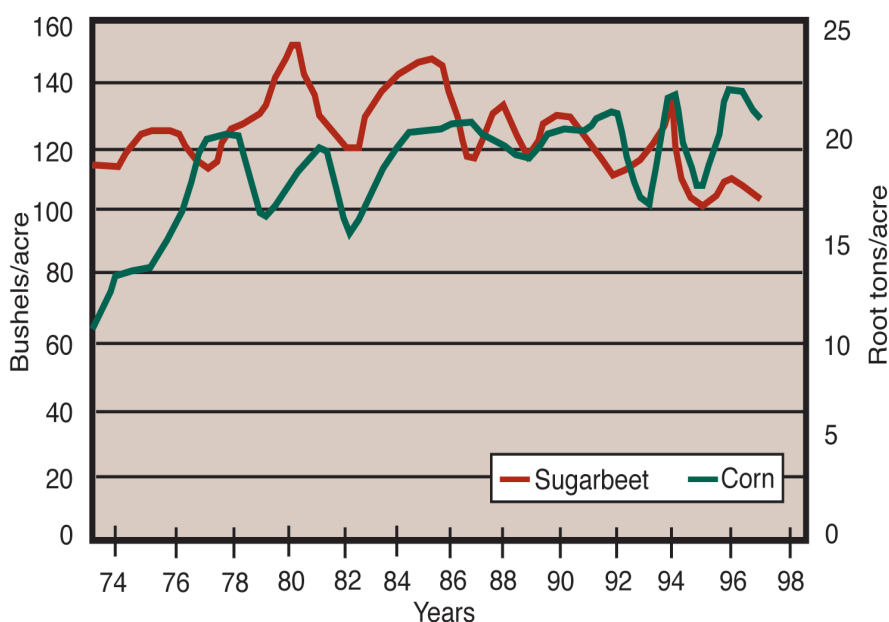
Sugarbeet production by region for 1985, 1990, 1995, and 1998.

*Nebraska's 74,000 acres of sugarbeet are estimated to add \$60,000,000 to the local economy annually.*

rial Sugar (three factories). Average sugarbeet yields in the United States and in the Great Plains have fluctuated over the past 25 years with only modest increases in production over this period. Compared to increases in corn yield in the United States over this same period, development of new varieties and production practices with sugarbeet have not been as progressive as with corn (*Figure 1.2*). If sugarbeet is to remain a viable crop in the United States, progress needs to be made to increase yields and quality.

The purpose of the *Sugarbeet Production Guide* is to provide a concise reference for cost effective sugarbeet production. It is the aim of the many authors of this guide to provide clear explanations to support their recommendations. This guide doesn't, however, contain all the information needed for sugarbeet production. Sugarbeet growers and crop consultants should always consult pesticide labels and equipment operator manuals before applying pesticides and operating equipment. The authors of this guide want to convey the importance of integrating cultural practices, pest management, farm equipment and crop production into sustainable systems of sugarbeet production.

**Figure 1.2**  
Average corn grain and sugarbeet root yields in Nebraska from 1974 to 1998.



# Growing Sugarbeet to Maximize Sucrose Yield

Often it is said that sugarbeet growers are actually aiming to grow sugar (sucrose). Although that is true, it is not possible to grow maximum sugar per acre without careful consideration of what conditions enable sugarbeet to produce maximum sucrose yield. This section includes information on how the plant grows, critical periods in its growth, the factors that most affect sugar accumulation, and how to maximize sugar yield.

## The Importance of Photosynthesis

Photosynthesis, the process in green leaves that uses the energy of sunlight to capture carbon dioxide from the air and convert it into carbon-containing compounds in the leaf, is the key to sucrose production in sugarbeet, as it is the basis of all plant growth. It is through photosynthesis and subsequent leaf biochemistry that sucrose is produced. Thus, the primary objective of sugarbeet cultivation must be to maximize photosynthesis through the entire growing season. Secondly, factors under producer control affecting the distribution of the products of photosynthesis, the “photosynthate,” should be identified and manipulated so that the maximum photosynthate is directed to root expansion and sucrose deposition.

## Seasonal Variation in Sunlight

To understand sugarbeet growth it is necessary to consider how the availability of sunlight varies through the growing season, limiting the amount of photosynthesis possible. Solar radiation at the field varies with changing atmospheric conditions and daily and seasonal changes in sun position. In our relatively flat, open, low humidity growing area radiation tends to be fairly consistent from year to year. *Figure 2.1* is a plot, by month, of the 30-year (1961-1990) average and range for the daily amount of sun energy reaching the earth’s surface at Scottsbluff, Nebraska. Other locations within the scope of this publication would be expected to be quite similar. In the discussion of each growth stage we will see that this seasonal variation in availability of solar energy affects sucrose accumulation and influences how the crop should be grown.

## Growth Stages

For convenience, sugarbeet growth can be divided into six, easily recognizable stages (*Table 2.1*). Because sugarbeet is a biennial, requiring two growing seasons for completion of its life cycle, the last two stages — overwintering and regrowth (including stem elongation, flowering, and seed set) — are included in the full list of growth stages. While these stages are important when sugarbeet is grown for seed production, this guide will only review the four stages that occur when sugarbeet is grown as an annual for sugar production.

**Table 2.1**

Growth stages of sugarbeet and approximate duration of each stage.

Growth stage	Approximate weeks in stage
Germination and emergence	3-4
Canopy development predominates	6
Storage root growth predominates	9
Pre-harvest (preparation for winter)	5-6
Overwintering and vernalization	(through winter)
Stem elongation, flowering, and seed set	(second growing season)

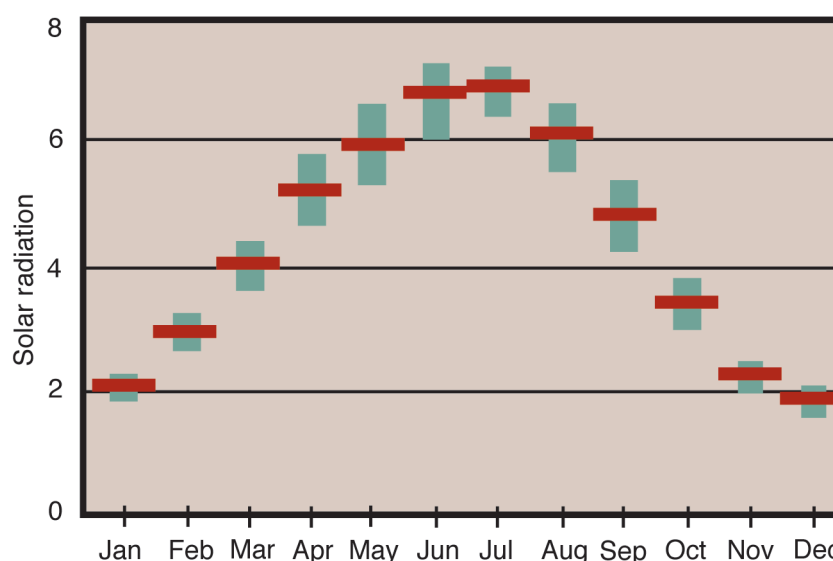
### Germination and Establishment

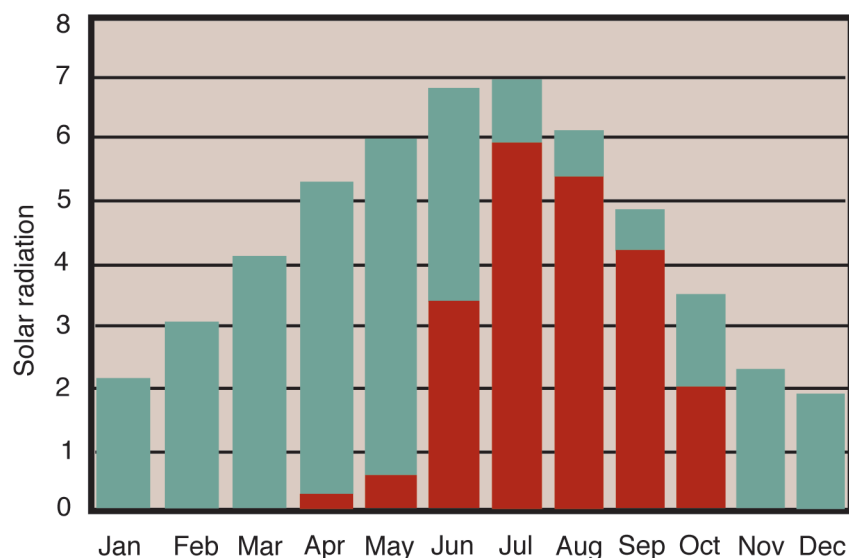
The importance of the first growth stage – germination and plant establishment – cannot be overemphasized because maximum photosynthesis on a given area is impossible without a uniform, suitably dense stand. Germination and establishment are very temperature and moisture sensitive. Typically, sugarbeet are planted as early in the spring as is feasible, based on long-term average and range in soil temperature, date of last freeze, precipitation pattern, etc., and modified by evaluation of the weather pattern and predictions for the planting year. Both soil temperature and soil moisture affect sugarbeet seed germination. Germination does not occur until soil temperature reaches 37°F, and germination at such a low temperature requires the liberal presence of water. The importance of seedbed preparation, seed quality, seed placement, and early irrigation are discussed and recommendations for our growing area are presented in other sections of this publication. Recommended plant populations also are discussed later, and are of great importance. Too many plants per acre leads to mutual shading and crowding effects on root size, yet too few plants means less than maximum interception of sunlight throughout the growing season. In either case there will be less than maximum sucrose yield.

**Figure 2.1**

Average daily solar radiation, by month, at Scottsbluff, Nebraska.

Data are 30-year averages (1961-1990) from Weather Bureau Army Navy (WBAN) database. Green bars show the 30-year range for the month, and the horizontal red line shows the 30-year average. Radiation is measured in kilowatt-hours per square meter per day.





**Figure 2.2**

Daily average solar radiation, by month, at Scottsbluff, Nebraska. Data are 30-year averages (1961-1990) from Weather Bureau Army Navy (WBAN) database, in kilowatt-hours per square meter per day. Red bars show the approximate monthly proportion of available energy intercepted by sugarbeet.

After sugarbeet germinate and emerge, seedling growth typically is very slow, mainly because leaves appear slowly under cool temperatures. Only two or three small leaves per week appear at first. During the period of germination and establishment, usually mid-April through May, the amount of solar radiation reaching the field is high (*Figure 2.1*), yet there is very little sugarbeet leaf surface area available. As a result, most of the arriving solar energy is “wasted” from a sugarbeet growth perspective — that is, it is not intercepted for photosynthesis. *Figure 2.2* illustrates the amount of early-season solar radiation that is not captured because of insufficient leaf area. It is obvious why so much emphasis is placed on early planting and on managing the factors that affect early growth to canopy closure. The early part of the growing season provides one of the best opportunities for increasing light interception, and anything that contributes to a good, healthy, early stand will pay dividends at harvest.

### Canopy Development

Both the rate of leaf appearance and leaf size increase as temperatures warm. Once sugarbeet plants are well-established and have produced four to six true leaves, they enter the canopy growth phase during which photosynthate is used mainly to produce the above-ground part of the plant, the leaves and petioles, collectively called the canopy. During this growth phase most of the dry weight gain of the plant occurs in the canopy (*Figure 2.3*). Leaves are produced throughout the season, and early leaves do not live as long as later leaves. At canopy closure there typically is about three times as much leaf upper-side surface area as soil surface area. That is, at canopy closure the plants on an acre of land will have approximately three acres of upper leaf surface area. Light interception reaches a maximum at about this time. About 80-90 percent of the incident radiation can be captured if all other factors are optimal; some radiation always is lost through reflection, sunflecks that pass through the canopy without striking a leaf, stand gaps, etc. It may seem odd that about three times as much photosynthesizing leaf surface as soil surface is required to reach maximum light interception, but remember that the sugarbeet canopy is tightly packed, with much mutual shading and crowding of leaves along the crown (the plant’s short stem). Thus, some areas of leaf overlap are not fully exposed to the sun and are relatively ineffective in photosynthesis.

*The key to maximizing sucrose yield is to maximize light interception and photosynthesis throughout the life of the plant.*

## Storage Root Enlargement and Sugar Accumulation

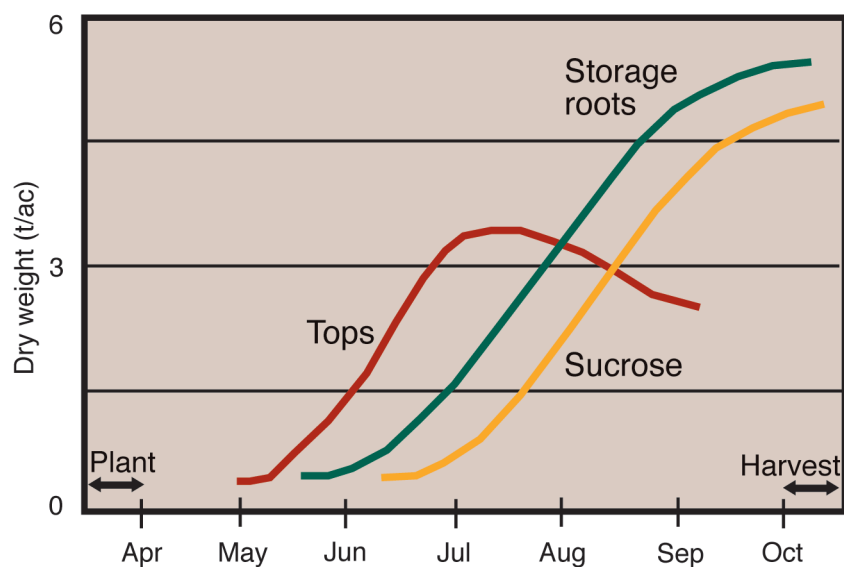
Some root growth also is occurring during the canopy growth phase, but most of the plant's weight gain at that time is in the canopy. By about mid-season, canopy growth normally slows down and canopy dry weight becomes stable, eventually even decreasing in late season (*Figure 2.3*). At some point after canopy closure, under the influence of environmental cues, sugarbeet is genetically programmed to decrease leaf production and to begin increasing root size and sucrose storage in preparation for winter. Internal signals instruct the plant to divert much of the daily photosynthate from canopy formation to storage root enlargement and the storage of sucrose as an energy reserve. In the full life cycle, the stored sucrose later would be used to provide energy for cellular maintenance, for all the biochemical processes that must continue as the plant overwinters, and for initiation of regrowth and reproduction.

As the root growth phase progresses, the storage root rapidly enlarges and gains weight, both in the taproot structure itself and in the sucrose stored within that root (*Figure 2.3*). In other words, root growth becomes predominant. Canopy weight remains stable for a time as most photosynthate is diverted away from leaf formation, then eventually the canopy weight begins a gradual decline as more and larger leaves die than are produced to replace them. The dry weight curves in *Figure 2.3* illustrate ideal growth patterns for maximum sucrose production. It is during this growth stage that maximum daily rates of sucrose accumulation in the taproot occur. Earlier in the growing season daily solar radiation was greater, but insufficient leaf surface was available to intercept it fully, or the photosynthate produced was being used to produce more leaves and petioles rather than being stored.

## Pre-Harvest Stage

During the pre-harvest period of September and October, decreasing light intensities and temperatures do not allow the higher rates of photosynthesis that occurred in mid-season. In September our daily solar radiation averages about 70 percent of the mid-season maximum, and in October the daily radiation average is only about 50 percent of the maximum (*Figure 2.2*). Once the full canopy is formed in mid-season, it is enough for maximum interception of the lower amount of arriving radiation in late summer and early fall. The photosynthate formed during this time is directed strongly to root structure and sucrose storage, but the amount of sucrose stored each day gradually decreases with time as photosynthesis decreases (*Figure 2.3*). There is no “sugaring up” or “ripening” period, as sometimes is believed, and no environmental cue that leads to a sudden surge in sucrose accumulation. It is true that sugar expressed as percent of root fresh weight continues to increase through the pre-harvest period, and some of that increase is real — an accumulation of sucrose resulting from photosynthesis. However, sucrose also may **appear** to increase when, in fact, fresh weight is decreasing with progressive soil and root dehydration in preparation for harvest. Other factors not discussed here also may contribute to an apparent, but not real, increase in percent sucrose as measured by polarimetry.





**Figure 2.3**  
Seasonal growth curves (accumulation of dry weight) for the sugarbeet canopy, the storage root, and stored sucrose. The curves are typical of a crop grown for maximum sucrose yield.

## Maximizing Sucrose Yield

**T**he key to maximum sucrose yield is maximizing light interception throughout the life of the plant. With this in mind, it is easy to identify several important factors affecting light interception. Of course, environmental factors which can't be controlled are very important — temperature, precipitation quantity and type (rain/hail), seasonal variation in solar radiation, cloud cover reducing radiation intensity reaching the field, soil type and structure as it affects nutrient availability, etc. These factors alone cause considerable year-to-year variation in sugarbeet yield. The focus of this guide, however, is on those factors we can affect. Here we will simply enumerate the factors; each of them is discussed in greater detail in subsequent chapters.

First, anything that affects stand establishment is important in determining how quickly plants attain sufficient canopy to maximize light interception. Seedbed preparation, seed quality, seedling emergence, plant growth, row spacing, and arrangement all are important in the initial growth phase of sugarbeet. Because water is important throughout growth, it must be provided adequately until the pre-harvest stage when some drying of the soil and roots is acceptable. Irrigation method and quantity affect all aspects of plant growth and light interception. It is important to minimize wilting as much as possible; wilted plants are not photosynthesizing appreciably. Pathogens, pests, and weeds must be controlled because they also affect light interception. Diseases causing foliar symptoms can reduce light interception directly, and other types of diseases can affect various aspects of the health of the plant and decrease its ability to photosynthesize at a maximum rate. Weeds compete with the sugarbeet for light, water, and nutrients, all potentially affecting photosynthesis.

*Applying more nitrogen than needed for vigorous early season growth results in more tops, not more sucrose yield.*

The necessity for nutrient management is obvious, as leaves and all other tissues must be supplied with required nutrients that are not sufficiently present or available from the soil. The single most important nutrient is nitrogen and will be addressed in detail later (see *Chapter 8, Fertilizing Sugarbeet*). Nitrogen is essential for rapid expansion of leaves, so it must be available in the soil from sugarbeet germination to canopy closure. After that time, however, nitrogen in the soil should be depleted because “nitrogen drives canopy formation.” As has been discussed above, sufficient canopy has already been formed by mid-season; after that, gradually decreasing light intensity and temperature limit photosynthesis. The canopy that already exists is sufficient for maximum photosynthesis under reduced light intensity, and the formation of more canopy cannot contribute to more photosynthesis. Of great concern is the production of large, late, dark green leaves, which will occur if nitrogen levels in the soil are not depleted or are maintained due to late mineralization. Such late leaf production uses photosynthate that otherwise would be used to increase root structure and stored sucrose.

Sugarbeet is unlike other crops, in which more nitrogen tends to result in more yield of the economic product. In sugarbeet, more nitrogen than needed for vigorous early season growth results in more tops, **not** more sucrose yield. Worse yet, excess late nitrogen has serious negative effects on root purity and therefore on sucrose extraction during sugarbeet processing. Producers should aim for a nitrogen management plan that drives canopy formation to mid-season closure, then keeps the canopy at a moderate size through the remainder of the growing season. This assures that late-season photosynthate has been devoted to root and sucrose yield, not to unnecessary canopy structure. It is quite acceptable for the canopy to become light green to yellow-green in color by September or October as nitrogen from the leaves is remobilized and returned to the root. The yellowed leaves still retain enough photosynthetic capacity to fully use the much decreased amount of sun energy that is available. Conversely, a large, dark-green late season canopy simply indicates that photosynthate has been used for too much above-ground production and maintenance, at the expense of root yield and sucrose storage. Maximum sucrose yield does not occur at maximum root yield, but at something less than maximum root yield. Thus, one should not aim for maximum tonnage, but for a healthy, properly fertilized crop that contains the most sugar and minimizes transportation costs.

Maximizing sucrose yield is a realistic goal for sugarbeet growers. Each chapter that follows will provide useful information about the most important growth factors that growers can control. As you read each chapter’s recommendations, remember that they are experimentally derived for our area, and that the goal of each recommendation is to maximize plant growth so as to maximize light interception through the entire season. That is the secret to success in sugarbeet cultivation.

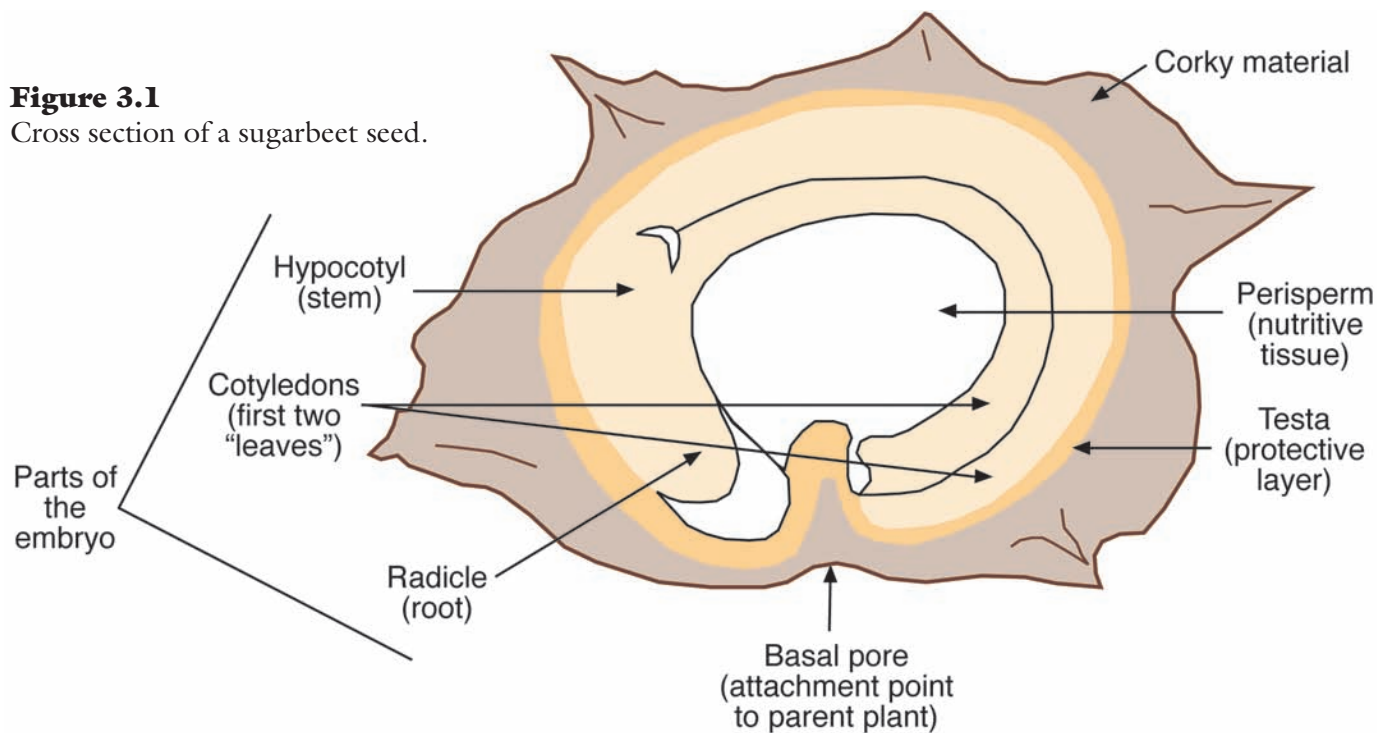
*By John A. Smith, Lee W. Panella, and C. Dean Yonts*

**S**eed is one of the most important factors in sugarbeet production. Without a uniform plant population of a sugarbeet variety adapted to the growing region, the producer will have difficulty achieving economical crop production. Seed selection will be one of the most important decisions a grower will make. A careful examination of sugarbeet seed, the seed germination process, and the development of sugarbeet varieties can be helpful in making crop management decisions and improving crop profitability.

## Seed and Germination Process

**I**n the second year of growth sugarbeet plants flower and produce seed. A seed consists of the embryo and its nutritive tissue or perisperm, together with a covering layer (*Figure 3.1*). Included in the embryo are two cotyledons or “seed leaves”: the hypocotyl, which will form the new plant’s stem or crown, in the case of sugarbeet; and the radicle or embryonic root. The relatively small size of sugarbeet seed means the amount of nutritive material is limited, so conditions must be just right for the seed to germinate and grow quickly into a healthy seedling. When seeds are first formed on the mother plant they initially contain large amounts of water, but as they mature they lose water and by harvest the water content is low. At this point seeds are in a resting stage and can be stored for months. This resting stage is broken as the seed germinates. There are three phases to seed germination: uptake of water by the seed; a metabolizing process in which life resumes after a state of suspended animation; and germination. The seed cap regulates the entry of water into the inner seed embryo. Within the seed cap are germination-inhibiting compounds that in some cases must be leached away before germination can begin. During germination the root protrudes through the seed cap and then the cotyledons emerge.

**Figure 3.1**  
Cross section of a sugarbeet seed.



*A quality sugarbeet crop starts with careful seed selection and develops with the use of good management practices.*

## Seed Germination and Relationship With Field Emergence

To have the potential for high yielding, high quality sugarbeet, the crop must first have established plants at the correct population and uniform plant spacing within the row. This “crop stand” is dependent upon “percent emergence” or more specifically the percentage of seeds planted that actually produce established plants. Many factors influence field emergence, but one of the most important is the “potential” of the seed to produce a plant in the grower’s field. Germination is one common measurement used to infer seed quality or potential for emergence. Germination is often presented as “laboratory germination” or the “labeled germination” cited on the seed box.

### Laboratory Germination

Laboratory germination is ordinarily referred to as the percentage of the seed that will produce a seedling under optimum laboratory germination conditions. It is not intended to represent the percentage of seeds that will emerge in the field. Detailed rules, established by the seed industry, define the multi-step testing process. In the optional first step, sugarbeet seed can be soaked in water at 77°F for 16 hours, rinsed, and dried for 2 hours before being placed in the germination media. The seed is then placed between paper towels, between specially designed blotter paper, in pleated germination paper (*Figure 3.2*), or on sand. Moisture is supplied to the substrata for the entire germination period to provide optimum moisture uptake by the seed. The amount of moisture can be adjusted for specific seed or seed coating types. The temperature can be a constant 68°F or alternate between 16 hours at 68°F and 8 hours at 86°F. The first seedling count is taken after three or four days and the final count is taken after ten days. Specific rules apply to coated or pelleted seed.

### Labeled Germination

Each state has regulations that describe certain aspects of the advertisement, sale, and packaging of seed. These seed laws vary among states but often cover how seed is to be tested, what information is to be included on the label of the seed container, and definitions of terms such as dormant seed, hard seed, and germination. The intent of the germination value listed on the seed container is that it represents the laboratory germination of the seed in the container, with an allowable deviation. In practice, the labeled germination value might represent the actual tested laboratory germination value, it might be several

percentage points below the tested value to avoid any challenges to the value, or it could be a value that represents the lowest test value anticipated with any seed sold in that growing area or year to simplify preparation of container labels.

The bottom line is that in practice the germination value on the seed container label is of limited use for predicting field emergence because it may not accurately represent the actual laboratory germina-

**Figure 3.2**

Pelleted sugarbeet seed in a laboratory germination test using pleated germination paper.



tion of the seed in the box, and because there are so many variables in the field not represented by the ideal laboratory germination. However, if the seedbox label germination value is below 90 percent, be concerned that the emergence potential of the seed might be lower than desired.

### Seed Vigor Tests

Since the laboratory germination test is intended to test the ability of seed to germinate (not emerge) under optimum conditions, the seed industry has developed a number of seed tests to predict the ability of the seed to perform under varied or less than optimal conditions typically found in the field. These tests are often called “vigor” tests. Most vigor tests use some form of stress during germination and/or emergence that can cause weak or inferior seed to not germinate or emerge. Examples of these imposed stresses include high or low temperature, low moisture, high relative humidity, specific chemicals added to the water, and mechanical impedance created by packed soil or sand above the seed. Accelerated-aging tests are designed to cause low quality seed to deteriorate more rapidly than high quality seed. Accelerated-aging could be initiated with conditions that favor rapid germination but also cause seed deterioration. These conditions include high temperature and high humidity. Saturated salt solutions have also been used for testing seed vigor. The water in the germination container is replaced with a saturated-salt solution which modifies or delays moisture uptake by the seed. Examples of salt solutions include those with sodium chloride, potassium chloride, and sodium bromide.

One of the most popular seed vigor tests is the packed sand test (*Figure 3.3*). This laboratory test includes placing seed on a layer of packed sand and covering the seed with another layer of packed sand. This test more nearly represents the combination of stresses imposed by field conditions because it can be conducted with a specific sand moisture content and temperature, and the seed must emerge through the packed sand layer before being counted. At least one U.S. seed company uses this test on all seed lots to eliminate any seed lots that have low vigor and low potential to emerge in the field.

In practice, seed companies use laboratory germination in conjunction with other vigor tests to evaluate and control seed quality. Although these tests cannot guarantee a minimum field emergence, by comparing results of standardized laboratory tests, seed companies can assure growers of high quality seed with good potential for high field emergence.



**Figure 3.3**  
Sugarbeet seedlings emerging in a packed sand test.



## Relationship of Laboratory Seed Tests to Field Emergence

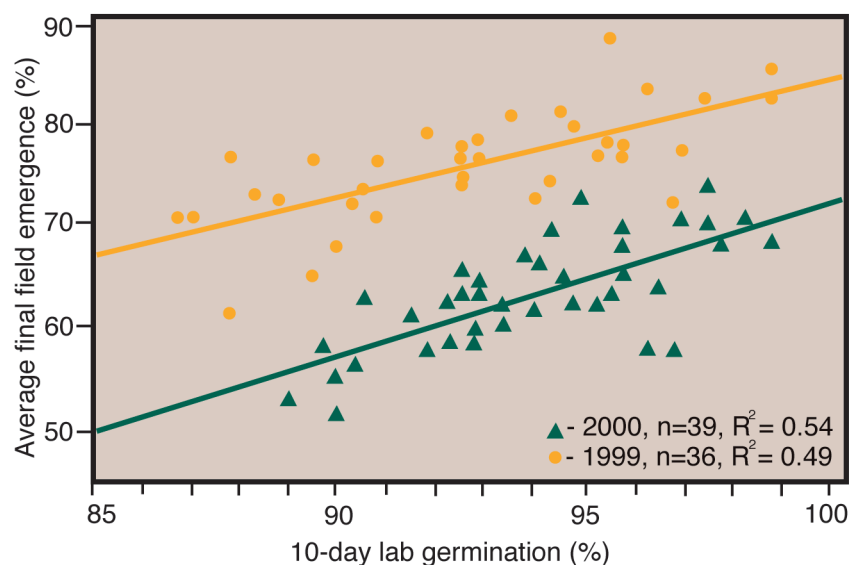
Field germination and emergence conditions can vary greatly from year to year, growing area to growing area, and even from hour to hour within different sections of the same field. These variables include soil moisture; soil temperature; soil type; seedbed preparation; seed depth; seed placement, soil covering and firming by the planter; weather-induced issues such as frost or soil crusting; and seed quality. With this many variables, a laboratory seed test can never be expected to accurately predict seed emergence in any particular field.

Laboratory tests, however, can be useful in comparing the emergence potential of two or more varieties. There is good evidence that standardized laboratory tests can predict, with reasonable accuracy, the relative ability of one seed sample to emerge in the field compared to another seed sample. In other words, a seed sample that performs better than a second sample in a standardized laboratory test also can be expected to emerge better in the field. Several research projects have shown that the packed sand test can rank seed samples from different varieties or seed lots for field emergence. University of Nebraska tests have shown that the standardized laboratory germination test can provide general information, on a ranking or comparative basis, of how different seed lots will emerge in the field (*Figure 3.4*).

To maximize sugarbeet root yield and quality, growers must target specific plant population and plant spacing goals. To achieve these goals, growers must manage field emergence and be able to predict seed performance. The seed industry has a number of tools to assure and control seed quality and the ability of the seed to emerge in the field. More of this information must be made available to the growers who should use it when making seed selection and planting decisions.

## Steps in Processing Sugarbeet Seed

- Harvest in the field.
- Clean the seed. Remove plant parts and foreign material.
- Polish or mechanically process to reduce seed thickness and rough edges.
- Place seed in boxes or totes for shipment to seed processing facilities.
- Reclean and size seed. Additional polishing or forming may be done.
- Size again after polishing or forming.
- If necessary, use a gravity table to improve seed quality.
- Steep or prime seed, if desired.
- Apply type and amount of coating desired (*Figure 3.5*). The amount of coating ranges from as little as 3 percent by weight to a complete pellet.
- Apply fungicides, ordinarily Apron and Thiram, to control seedling diseases.
- Apply Tachigaren fungicide or Gaucho insecticide to coating, as an option.
- Add coloring during coating for seed identification.
- Screen final coated seed product to assure size.
- Use laboratory germination test and other laboratory tests to monitor and assure seed quality at several steps within this process.
- Box and label seed for sale.



**Figure 3.4**

Relationship of laboratory germination test with field emergence for seed used in 1999 and 2000 University of Nebraska Sugarbeet Variety Tests. Each point represents four replications of laboratory germination and six replications of field emergence at seven sites in 1999 and five sites in 2000.

## Seed Processing

**E**xtensive refinements have been made in sugarbeet seed processing since the development of the industry more than 100 years ago. There are many variations in processing among seed companies and among seed lots or final seed products within a company, however, there are general processing steps that apply in some combination and some order for almost all sugarbeet seed. The particular steps and the order of steps depend on the condition or quality of the harvested seed and the final seed specification (coating, chemicals applied).

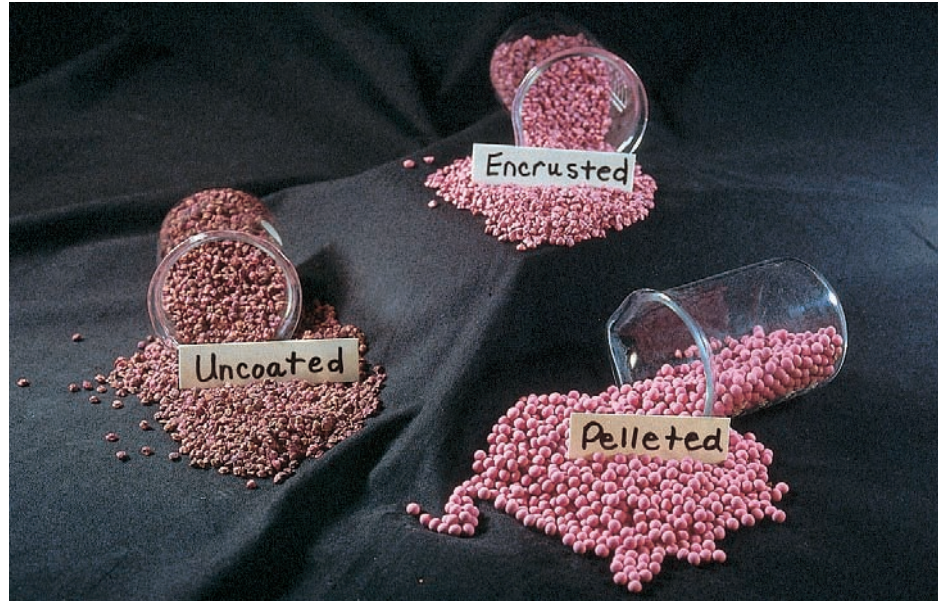
## Influence of Seed Size on Field Emergence

**W**hen grown for seed, the sugarbeet plant produces a wide range of seed sizes. “Size” can mean size of the external seed cap or the size of the living embryo within the seed cap. Both designations of “size” can have implications for the ability of the seed to emerge in the field. Sugarbeet seed can have a very large or thick seed cap, which can increase the time required for moisture movement through the seed cap to the embryo. Seed polishing can have some influence on the thickness of the seed cap. The embryo — the living entity of the seed that actually produces the seedling — also can vary in size. It is generally thought that, other factors being equal, the larger the embryo the more “vigor” the seedling will have to emerge and become an established plant.

The question of whether a large seed will emerge in the field better than a small seed involves several issues. If somehow two sugarbeet seeds could be taken from the same plant and have the exact same thickness and shape of seed cap, but have different sized embryos, then it would be expected that the seed with the larger embryo would have more energy reserve and more vigor to emerge from the soil. This idealistic comparison of seed “size” is rarely possible in real life because there are too many other factors involved when comparing two samples or seed lots. Seed “quality”, as measured by a standardized laboratory germination test or a commonly used vigor test, is probably far more important for comparing seed lots for ability to emerge in the field than the issue of seed size.

**Figure 3.5**

The sugarbeet seed that is planted almost always has some type and quantity of coating to improve plantability and to secure any pesticides added to the seed.



## Pesticides Applied to the Seed

Pesticides may be applied to sugarbeet seed during seed processing. Two fungicides, Apron and Thiram, are usually added to U.S. sugarbeet seed for control of seedling diseases. Two other pesticides, Tachigaren and Gaucho, can be added to the seed coating for specific production problems. Tachigaren, a fungicide, can effectively control early seedling stages of aphanomyces black root. Gaucho is a systemic insecticide used for certain insect or insect-like pests of seedling roots or leaves.

## Seed Steeping and Priming

A number of seed treatment processes have been developed to improve the percentage of seeds that germinate and emerge in the field, or to increase the rate of germination and emergence. Two processes frequently used for sugarbeet seed include steeping and priming. Both terms apply to general seed treatment processes and both processes can overlap. Steeping generally refers to treatments intended to leach naturally occurring germination inhibitors from the seed coat using mild chemical-water solutions. Removing germination inhibitors often will provide increased germination or increased emergence.

Priming is a term that usually refers to a technique that actually initiates the germination process and advances it to a predetermined stage. At this point germination can safely be stopped, and the seed can be further processed (coated, pesticides applied, boxed). When the seed is planted in a soil environment with adequate moisture and temperature, the seed resumes germination from nearly where it was at the end of the priming process. The goal is to shorten the germination period required in the field and ultimately reduce the field emergence period by several days. Field research suggests the most benefit from primed sugarbeet seed occurs under moist, cool soil conditions where emergence would otherwise be slow.



## Seed Storage

**S**eed should be stored and handled very carefully. Temperatures above 90°F for extended periods can reduce seed quality and emergence potential. Do not store seed in hot buildings, in pickup truck cabs, under direct sunlight or other locations that can attain high temperatures. Preferably store in environments that are dry, have low humidity, and are between 35°F and 70°F.

Use care while physically handling sugarbeet seed in the seed box or when pouring from the seed box into the planter hopper. Sugarbeet seed is fragile and must be handled with caution. Long drops into a planter hopper or dropping seed boxes can reduce seed quality.

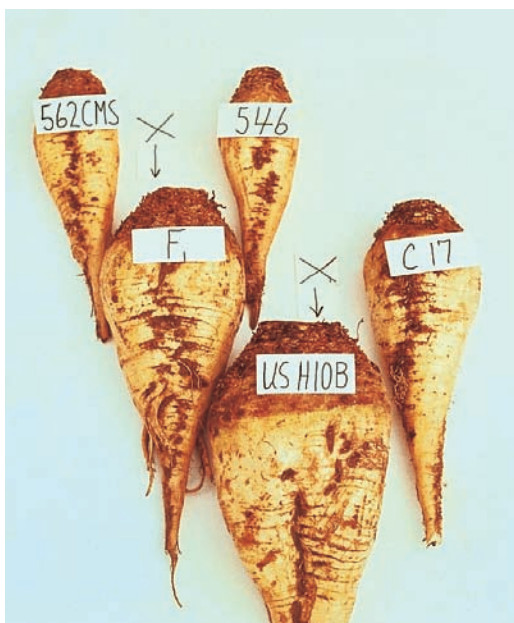
If possible, return any unused seed to the seed supplier after planting. If seed is carried over to the next year and stored on-farm, keep it in a dry, low humidity, cool environment. If properly stored, good seed will not measurably deteriorate for one year. Sugarbeet seed that is stored for more than three years after harvest, even under good storage conditions, can be expected to have reduced performance.

## Types of Sugarbeet

### Hybrid Seed

All commercial sugarbeet seed sold in the United States is hybrid seed. Hybrid seed is beneficial because it exhibits a phenomenon called hybrid vigor (or heterosis). Basically this means that seed from two slightly inbred parents produces roots bigger and sweeter than either parent.

Hybrid sugarbeet seed production takes advantage of a genetic-cytoplasmic male sterility system (CMS), in which one of the hybrid parents is unable to produce pollen. This makes the plant functionally female so it can be pollinated by a pollen-producing parent (pollinator). The seed produced on the CMS parent has half of its genetic material from the pollinator parent and half from the CMS parent. Often this seed is harvested, grown out the next year and crossed to a third parent to produce the final hybrid (*Figure 3.6*). Three parents often give much higher seed production per plant and also allow for different specific characteristics to be brought into the hybrid, e.g., a parent for high sugar, a parent for resistance to a specific disease, and a parent for high tonnage (or resistance to a second disease).

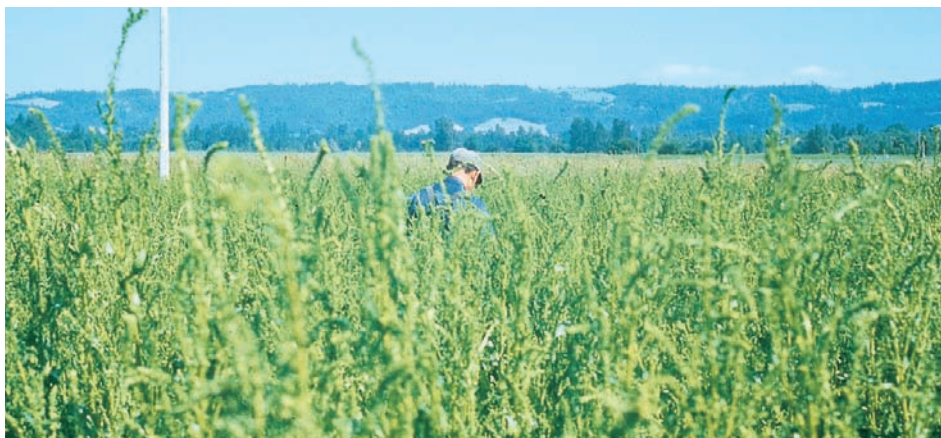


**Figure 3.6**

The upper two roots are hybridized to form the F1, which was hybridized one more time (to C17) to form the hybrid (US H10B). The gain in size through the two generations that go into making the hybrid is due to hybrid vigor (or heterosis).

**Figure 3.7**

A sugarbeet seed field in Oregon in 1997. This seed was being increased by the West Coast Beet Seed Company for a USDA-ARS germplasm release.



Almost all seed produced in this country is produced in Oregon, and most is produced by the West Coast Beet Seed Company. This company is run jointly by all the sugarbeet seed companies operating in the United States for the express purpose of producing hybrid sugarbeet seed. It has been in operation since 1940 in the Willamette Valley.

### **Multigerm vs. Monogerm**

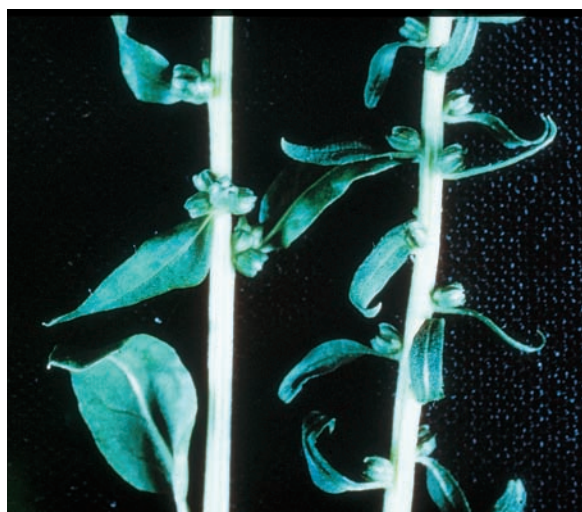
Sugarbeet seed is naturally multigerm. This means that the seedball is really two to eight individual seeds (from flowers located next to each other) that have grown together. Any number of those individual seed could germinate which would mean two to eight seedlings growing from the same spot. This is why older sugarbeet varieties were “singled,” i.e., all except one of the seedlings were removed with a short handled hoe. In the 1950s a genetic monogerm sugarbeet was found and brought into production. This type of sugarbeet has only one flower at each leaf and produces seedballs containing only one seed. The development of monogerm seed has allowed precision planting and mechanization of the planting process by alleviating the need to single beets by hand. All commercial seed sold in the United States is produced from CMS sugarbeet parents and is monogerm.

### **Triploid vs. Diploid**

Sugarbeet occur naturally as a diploid. This means that there are two copies of each chromosome (the carriers of genetic material), one from the paternal

**Figure 3.8**

Two sugarbeet flowering stalks. One is multigerm and has more than one flower above where the leaf attaches to the stalk (leaf axil). When mature these individual flowers grow together to form a seedball which can produce two to eight seedlings. The other stalk is from a monogerm plant and there is one flower at each leaf axil. This plant produces seedballs containing only one seed.



parent and one from the maternal parent. This is the same as in most animals, including humans. Plants, however, can tolerate having their genetic material doubled. This is done chemically, and the resulting sugarbeet has four copies of each chromosome, two from each parent. (This plant is called “tetraploid.”) If such a plant is used as a hybrid parent, it contributes two copies of

its genetic material and the other parent (if diploid) contributes one copy. The resulting hybrid seed has three copies of the sugarbeet genetic material, and is called “triploid”. Such hybrids have larger leaves and may emerge more quickly. There is still a lively scientific discussion of whether triploid or diploid hybrids perform better (diploid seed is the normal result when both parents are diploid), but there seem to be excellent varieties of both types. As with all commercial varieties, it is best to try a small area on representative fields on your farm and judge the performance under your growing conditions.

### E vs. Z types

You will hear some varieties referred to as E or Z or EZ types. The E varieties have higher tonnage but lower sugar content. The Z varieties are sweeter (higher sugar content) but have reduced tonnage. And the EZ varieties are a compromise — good tonnage with higher sugar. This system came out of Germany and is somewhat dated, but there does seem to be a cost in tonnage for extremely high sugar production and a cost in sweetness for extremely high tonnage. In general, a variety either produces high tonnage or high sugar. Again it is always best to see how such varieties perform under your conditions before planting a large acreage to them.

## Variety Approval Process

**E**ach sugarbeet processor has a different approval process. In most cases the processing company and the growers have a joint committee that determines the rules for variety approval. In the case of cooperatives the processors and growers are the same. The following excerpt is from the approval process used by Western Sugar Company — Grower Research Committee:

“The purpose of testing is to assure that the best varieties will be available for both the grower and the processor. Approval for sale is based on three major criteria: Recoverable Sugar Per Ton, Sugar Loss to Molasses, and Disease Resistance. To gain full approval, a variety is compared to three Standard Varieties and must achieve 100 percent of their Indexed Value for Recoverable Sugar Per Ton while not exceeding their Indexed Value for Sugar Loss to Molasses. Adequate disease resistance must be present in areas where a disease is a general problem. Approval will be on an annual basis.”

A committee determines the procedure for conducting yield trials and tare sample analyses and which varieties are to be used as standard varieties. In most cases, the approval process is the average performance over a number of years with three years being the norm. Sugar processors also divide their growing areas into districts. Each variety must qualify for approval in each growing area, which may have a different set of standard varieties. For example, based on soil and climatic factors, there are three districts in the Western Sugar Company beet growing area.

“The Western Sugar Company beet growing area is divided into three distinct areas of variety adaptation. The “A” Area is defined as all acreage grown in Nebraska, Colorado, and Eastern Wyoming. The “C” Area shall consist of the Clark’s Fork Valley in the Billings, Montana factory district, and the entire Lovell, Wyoming factory district. The “D” Area includes the Yellowstone and Bighorn River drainages in Montana.”



Additionally, there may be some requirements of minimal levels of resistance to different pests in each of the growing areas. In area “A”, the Western Sugar Company — Grower Research Committee requires a moderate *Cercospora* leaf spot resistance, and in areas “C” and “D” a moderate level of curly top resistance.

## Pest Resistance

**S**ugarbeet plants and their wild relatives have varied natural resistance to many diseases that attack cultivated sugarbeet. Breeding varieties with resistance to different diseases is an important goal of many sugarbeet seed companies and the main goal of most USDA-ARS public breeders. The amount of disease resistance that a sugarbeet variety possesses can be measured in different ways. Greenhouse tests can measure resistance, artificial epidemics can be created in the field, or varieties can be planted in fields and locations that are known to have a history of disease problems. The varieties are scored on a standard scale that reflects the range of response to the disease from fully susceptible to very resistant. For most diseases, there is no immunity; however, a highly resistant variety will show little or no yield loss in the presence of the disease. As in yield trials, in these disease resistance nurseries, results are compared to standard varieties that have been grown commercially for many years. The minimal disease resistance discussed above is determined as a percentage (generally greater than 100 percent) of the disease score of standard varieties. Most sugar companies and cooperatives use a similar method for determining disease resistance. The disease nurseries are either managed by the industry (e.g., *Cercospora* leaf spot in the Red River Valley or curly top by the BSDF in Kimberley, Idaho) or by public researchers (e.g., *Rhizomania* — USDA-ARS in Salinas, California; *Cercospora* leaf spot and *Rhizoctonia* root rot — USDA-ARS in Fort Collins, Colorado) and the entries are coded so that only the submitting individual or company knows which varieties are being tested.

**Figure 3.9**

The USDA-ARS *Rhizoctonia* Nursery in Fort Collins, Colorado. The field is inoculated to create a very severe disease epidemic and the performance of commercial varieties can be compared to the performance of well known commercial check varieties to estimate disease resistance.



## Where to Get and How to Use Variety Performance Information

The variety performance information is critical in allowing growers to make the best choice of which varieties to grow. The joint sugar processor-grower committees make the variety trial information available to growers. It is extremely important that producers understand how these varieties were tested. For example, often, for the official variety yield trials, the seed is over planted and then thinned to an optimum plant density. This type of trial will not provide emergence information like a yield trial that was planted to stand.

In general, an attempt is made to provide the beets grown in these tests with the best possible growing conditions so that test results represent the maximum yield obtainable from the varieties. Most disease nurseries are managed to provide a very severe epidemic – in many cases more severe than would naturally occur in the field. This is why the information needs to be presented as a percent of some standard variety or comparison with some standard variety that many growers have seen perform under disease conditions.

Test results compare different varieties *under the conditions of the trial* – not necessarily under typical growing field conditions. Make sure you know the conditions of the

field in which the test was done. Before you switch to a large acreage of a new variety, plant a small area – large enough for you to observe how well the variety performs but not so large that potential losses would be

great. Save your tare slips from test areas and compare them with those from the rest of your fields. If the performance is good, plant a larger acreage next year – only you know what level of risk you are comfortable with.

If you have an area with chronic disease problems and there is a resistant variety available, consider using it. In some cases the yield potential of the resistant variety might be less than other varieties under perfect growing conditions but the resistant variety may outperform those high yielding varieties in the presence of disease – without the added cost of pesticide applications. The test results can provide you with the necessary information to make better decisions about what is going to be profitable for you. The approval process is dynamic. It will change from sugar company to sugar company or even within the same company from year to year. Growers must stay informed about the current rules and obtain the most recent test results.



**Figure 3.10**

Growers, seed representatives, and plant breeders check the performance of commercial varieties in an official yield trial in Berthoud, Colorado.

*Standardized laboratory tests are useful in comparing the qualities and emergence potentials of two or more varieties.*

## Sugarbeet Contract Specifications

The sugarbeet contract will determine how much and when growers are paid. It will spell out who is responsible for paying to have the beets taken to the piling station. The contract varies from company to company and year to year. Growers will need to understand the contract to maximize their profits. The sugar content, tonnage (after tare), and purity (loss to molasses) are often all part of the equation that determines how much growers receive for their beets.

## Relationship of Crop Quality to Factory Performance

Quality is a measure of how much potential refined sugar is lost to molasses in the purification process. When the beets are of low quality, it is much more difficult to refine the beet juice and losses are high. Extremely poor quality beets will cause the factory to slow down processing or even stop for a time. This means that productivity and profits for everyone suffer. Part of the loss in quality is due to storage. A slowdown in factory processing means that the beets stay piled longer and quality deteriorates even more. Quality starts with good management of the crop so that the quality at harvest is excellent. Exposure to diseases, damage to the root during harvest, and high dirt tare can all erode the quality of the beet going into the pile. Beets stored before processing **always** decline in quality over time, therefore, the better the quality of beets going into the pile, the better the quality of the beets after storage.

**Figure 3.11**

No matter how well you treat them, sugarbeet stored before processing always decline in quality over time. Therefore, the better the quality of the sugarbeet going into the pile, the better the quality of sugarbeet after storage.





*By Robert G. Wilson*

A sound crop rotation is a key component of effective pest management and stabilization of sugarbeet root yields. Sugarbeet hasn't always been grown in rotation with other crops. When sugarbeet production was initiated in Europe, some promoters of the crop felt sugarbeet could be planted in the same field year after year. This worked for several years until populations of beet cyst nematode increased and root yields began a rapid decline. It then became apparent that sugarbeet production could be stabilized if sugarbeet was grown in rotation with other crops.

Several long-term rotation studies were conducted in Nebraska, Montana, and South Dakota beginning in the early 1900s and continuing at some locations for 29 years. The results of these studies were similar: sugarbeet production improved:

- 1) when the crop was grown in rotation,
- 2) when the rotation included alfalfa; and
- 3) when crop rotation increased from a three-year to six-year rotation.

At the Nebraska location it became apparent that root-knot nematodes were affecting sugarbeet yields. The density of root-knot nematodes increased rapidly in two-year rotations, declined somewhat in a three-year rotation, but declined markedly in a rotation that included sugarbeet once every four to six years.

Crop rotation can be very effective in suppressing certain diseases and weeds. Generally crop rotation isn't effective against highly mobile pests such as aphids or diseases that are spread by wind. As a general rule the more frequently sugarbeet are grown, the more rapidly disease organisms or nematodes build up to damaging levels. Breaking this cycle by planting a crop the pest can't affect causes the number of disease organisms in the soil to decline.

A good example of this phenomena can be demonstrated with beet cyst nematode. Each year about 50 percent of the nematode cysts hatch and try to infect sugarbeet or weed hosts. If a host plant cannot be found, the nematode dies. If following sugarbeet, the nematode population was 50 cysts per gram of soil, one year later without a susceptible host the population would decrease to 25 cysts, after two years 12.5 cysts, three years 6.25 cysts, and four years 3.1 cysts. When the nematode population declines below the threshold level (the level of nematode which will not cause an economic yield loss), it would be economically feasible to again grow sugarbeet.

The type of crops grown in rotation and the position of sugarbeet in the rotation are very important factors to consider. *Rhizoctonia* root rot can affect sugarbeet, dry bean, potato, and alfalfa but does not affect corn or small grains. The effect of this disease can be reduced in a three- to five-year rotation by planting small grains before sugarbeet.

*Crop rotation can help break the destructive cycle of sugarbeet disease organisms building to damaging levels in the soil.*

In a similar manner the disease aphanomyces root rot can be reduced by crop rotation with nonsusceptible crops such as corn, soybean, potatoes and small grains. If sugarbeet follows susceptible crops like alfalfa, dry bean, sweet clover and clover, the disease incidence will increase. Cercospora leaf spot incidence will decline if sugarbeet are rotated with non-host crops and infected sugarbeet tops are plowed under. The disease rhizomania is an exception and is not reduced by crop rotation once disease symptoms have been observed on sugarbeet. Infected fields can be cropped to other non-host crops for up to 15 years and the disease will still be present in the field to infect sugarbeet.

Rotation also can improve weed control. Corn and small grains are usually more competitive with weeds than other crops. Both crops shade the soil rapidly and have many herbicides available to suppress weeds. Corn and small grains can be positioned as crops to reduce annual and perennial weed populations. Some effective crop rotations (see *Table 4.1*) for weed, disease, and nematode control would be: dry bean/corn/sugarbeet/corn where corn could be replaced with small grain and alfalfa for three years/corn or small grains/sugarbeet/dry bean. With all crop rotations make sure the herbicides used in the previous crop do not pose a carryover threat to the following sugarbeet crop.

**Table 4.1**

Example of effective crop rotations for sugarbeet.

Rotation No. 1	Year
Dry bean	1
Corn or small grain	2
Sugarbeet	3
Corn or small grain	4
Rotation No. 2	Year
Alfalfa	1
Alfalfa	2
Alfalfa	3
Corn or small grain	4
Sugarbeet	5
Dry bean	6



# Tillage and Seedbed Preparation

Some form of tillage is used prior to planting almost every acre of sugarbeet in the world. The intensity of tillage, the number of operations, the types of implements, the timing of operation, and the purposes for tillage encompass a wide range. In Nebraska, for example, there are successful systems that include as few as one tillage operation between harvest of the prior crop and planting sugarbeet, and there are systems that have seven or more tillage operations. Both tillage extremes can be used to successfully establish the crop, and each is useful for particular cropping situations. To maximize crop profitability the tillage system must be designed to fit specific circumstances for each grower.



**Figure 5.1**

Excellent crop of sugarbeet. A well designed tillage system is an important key for a successful crop.

## Purposes for Tillage

The tillage system and each individual field operation within this system must have specific purposes that contribute to the profitability of the crop. These purposes commonly include:

- killing weeds prior to planting;
- incorporating crop residue, manure, nutrients or herbicides into the soil;
- reducing soil compaction;
- facilitating a cover crop or manipulating the soil surface to minimize soil erosion;
- enabling the planter to provide consistent seed depth and spacing;
- conserving soil moisture;
- enabling soil moisture below the seed to move up to the seed as the soil surface loses moisture, and
- minimizing soil clods at seed depth for maximum seed-soil contact while providing some clods on the surface to minimize soil erosion and soil crusting.

## *Minimize tillage operations to conserve and maintain soil moisture at seed depth.*

The right type of tillage conducted at the right time with the right implement is a necessary and important part of sugarbeet production. Tillage at the wrong time with the wrong implement, or without a specific purpose, does not contribute to profitable sugarbeet production.

### **Kill weeds**

Sugarbeet should not be planted into growing weeds, even weeds that are just emerging. These weeds must be killed with tillage or a herbicide prior to planting or immediately after planting before emergence begins. An implement having closely spaced, narrow tines operated at a shallow depth (2-3 inches) will effectively kill small weeds and weeds that have germinated but not yet emerged, while preserving soil moisture and the seedbed. Large weeds must be killed with more aggressive tillage or with herbicides.

### **Incorporate crop residue, manure, fertilizer, and herbicides**

Excessive crop residue, particularly corn stalks, can interfere with the operation of the planter, cultivator, and ditcher, and present problems with emergence, thinning, and weed control. Manure and fertilizer should be mixed into the soil for maximum benefit and not concentrated in the seed zone where they could inhibit germination and emergence. Pre-plant herbicides often are most effective if incorporated into the soil at the correct depth with tillage. Each of these incorporation functions requires a specific implement for maximum effectiveness.

### **Alleviate soil compaction**

Development of the sugarbeet tap root can be adversely influenced by soil compaction. If the tap root encounters significant soil compaction, particularly in the top 12 inches of soil where the young and fragile root is developing, the

root often will sprangle and be less effective for moisture and nutrient uptake at lower soil depths. The sprangled root will often decrease root yield and increase harvest loss and root tare. If soil compaction is identified in the field, use



**Figure 5.2**  
Till-N-Plant zone tillage  
implement manufactured by  
Schagel Manufacturing Co.  
of Torrington, Wyoming.

tillage to minimize the problem. Appropriate tillage implements include the moldboard plow, a parabolic ripper, or a zone tillage implement with a ripping shank in the area where the sugarbeet row will be located (*Figures 5.2 and 5.3*). Vigorous soil shattering is the goal for alleviating soil compaction. This implies that the tillage must be deeper than the compacted layer, and the operation must be done when the soil is relatively dry, especially with a ripper implement.





**Figure 5.3**

Close-up of Till-N-Plant showing opening coulters, row cleaners, shank, closing discs, and firming basket.

The moldboard plow and parabolic ripper are very effective in alleviating compaction in a dry soil but can create other issues including high operating cost, large clods, bringing moist soil to the surface which decreases soil moisture, and creating a rough, loose soil condition that requires firming before planting.

### Reduce Soil Erosion

Sugarbeet are often grown in geographic locations and in soil types where soil erosion by wind is a serious problem from harvest of the previous crop until the sugarbeet plants are large enough to protect the soil. If the previous crop has sufficient surface residue remaining after harvest, such as corn harvested for grain, this residue is the most effective and practical erosion control method. Some residue can be retained on the soil surface even after planting to protect the developing sugarbeet plants. If the previous crop does not provide substantial surface residue after harvest, such as dry edible bean, soil surface roughening and cover crops are good alternatives. Surface roughening should be done in the fall to create soil ridges and a large number of stable soil clods on the surface. Implements that gently lift the soil are most effective. Good soil moisture and even a light soil frost will help create clods. A cover crop seeded in early September also can be very effective in retarding wind erosion but may require tillage for establishment of the cover crop. Cover crops will be discussed in more detail in *Chapter 6*.

### Improve Planter Performance

Tillage is often used to facilitate planter operation. The soil surface must be smooth enough that the planter can achieve accurate, consistent depth of seed placement. Distinct ridging can impair seed depth control and create planter bouncing or vibrations that cause seed metering problems. The soil surface should be “soft” enough to allow consistent seed furrow shape and depth by the planter opener, yet not be so soft that the planted row is at the bottom of a small depression in the soil. Water tends to settle in soil depressions, creating dense soil and soil crusting which impair seedling emergence. Small soil clods on the soil surface are useful for preventing soil erosion and minimizing soil crusting, but soil clods at seed depth prevent maximum seed-soil contact which in turn can reduce crop emergence.

### Conserve Soil Moisture

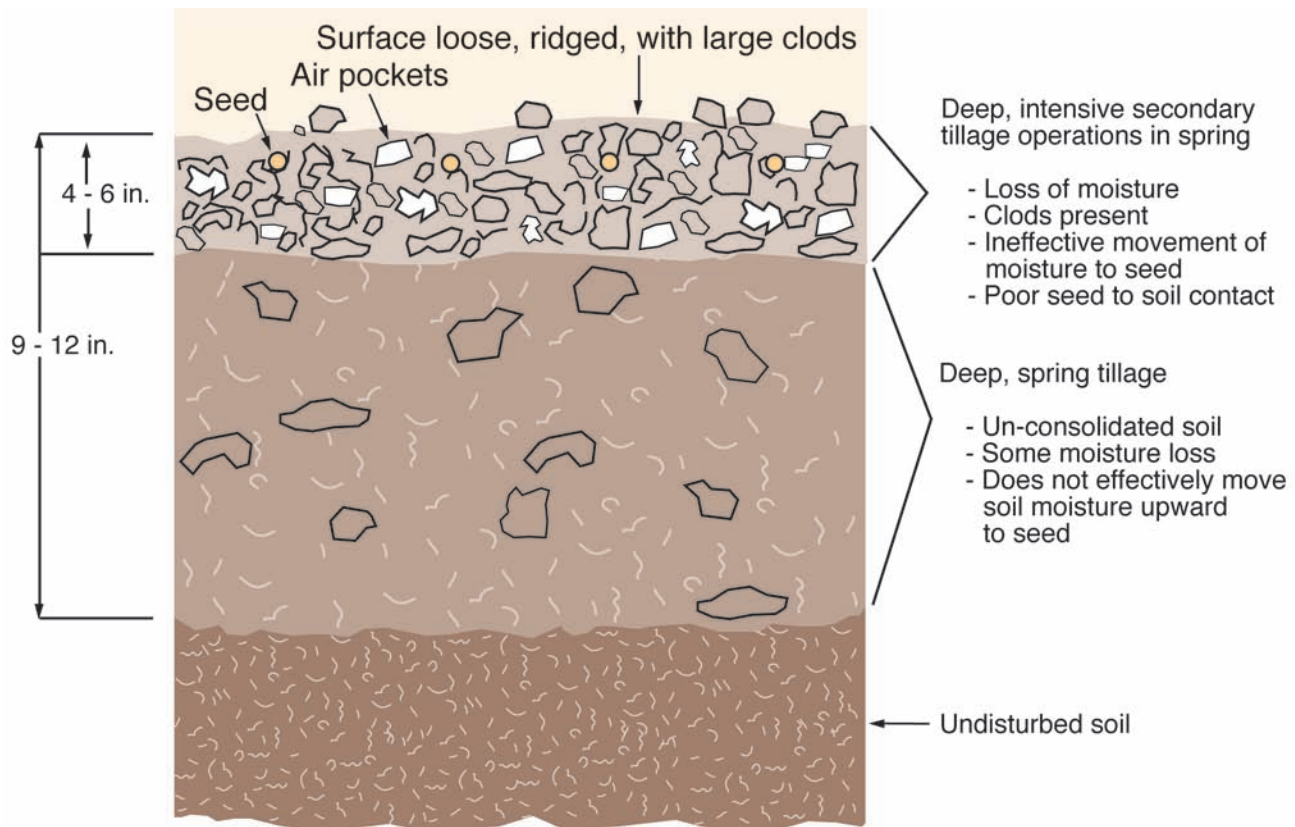
Conserving and maintaining soil moisture at seed depth are major problems during seed germination and seedling emergence. Each tillage operation exposes moist soil and accelerates soil moisture loss. Minimize the number of tillage operations, particularly in the spring prior to planting. Tillage implements that invert the soil and bring fresh, moist soil to the surface cause more soil moisture loss than implements that stir the soil in the horizontal plane without inverting the soil. Narrow vertical tines operated shallow will conserve more soil moisture than implements that invert the soil, such as a disk, moldboard plow, or “C” shaped tines. Implements that leave the soil surface firm (but not compacted) will conserve more soil moisture than implements that leave the surface loose.

### Utilize Sub-surface Soil Moisture

Soil that is in a “natural” condition can effectively move soil moisture from areas of relatively high moisture content to areas with relatively low moisture content. This movement can be vertical or horizontal. This is very important when the soil surface dries on a warm, sunny, windy April day when the soil below the seed has relatively high moisture content. If the moisture movement process is working well, the seed will receive adequate soil moisture much longer than if moisture could not move effectively within the soil. Soil structure, organic matter and activity of ever present biological organisms, including earth worms, are part of this moisture movement process. Intensive tillage is an un-

**Figure 5.4**

Depiction of soil condition following deep tillage and subsequent intensive secondary tillage operations, all made in the spring prior to planting. Result is loss of soil moisture, large clods throughout profile, and low potential to move moisture vertically.





natural process that disrupts soil moisture movement. Picture, in exaggerated scale, intensive tillage creating clods within the soil (*Figure 5.4*).

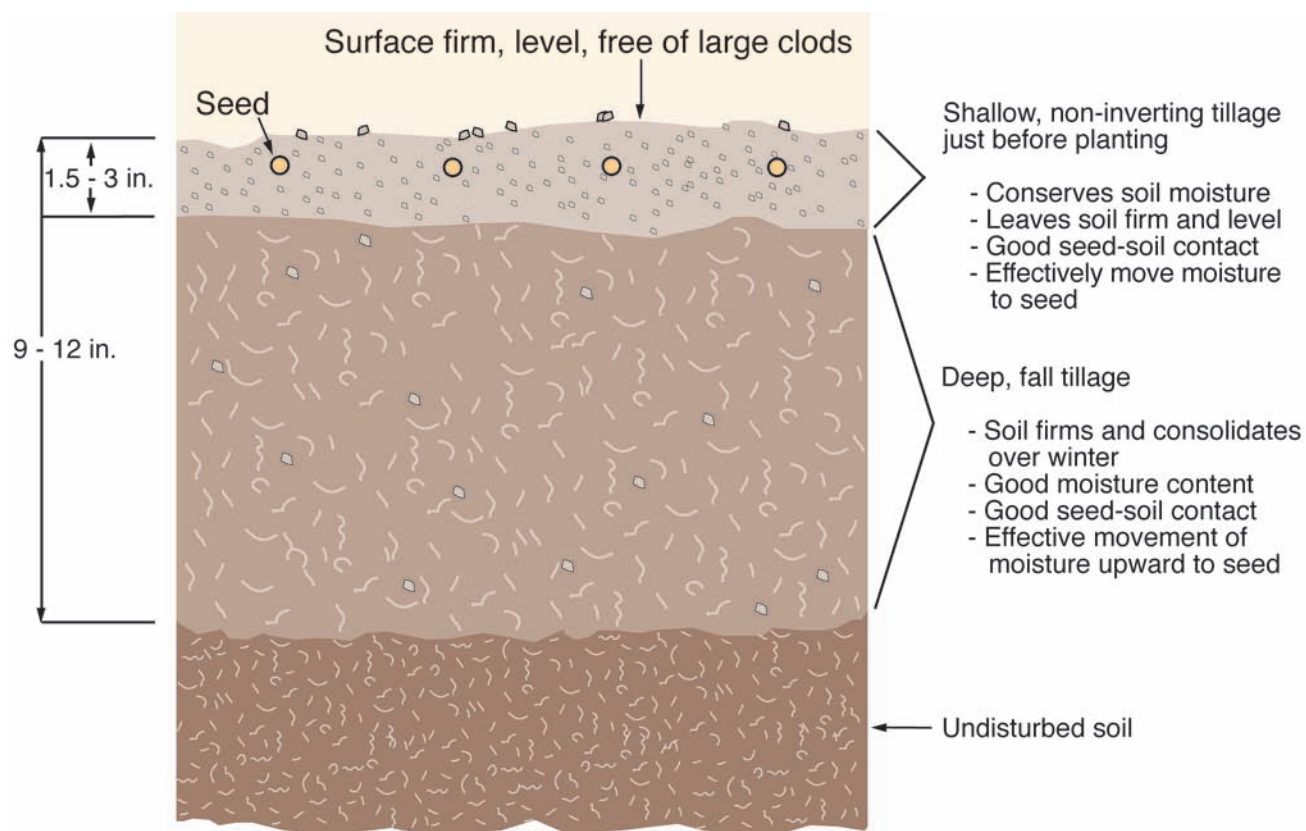
Compare this image with a “naturally occurring” soil condition. It is difficult for moisture to “wick” upward in soil containing clods compared to a soil that is more “natural”. Soil that has time to “regenerate” its condition, especially over the winter freeze-thaw, wet-dry cycles, can regain much of its ability to transfer moisture (*Figure 5.5*). The important point is that intensive tillage, especially tillage that creates clods, substantially decreases the ability of the soil to move moisture to the seed from below the seed where there may be abundant moisture.

### Soil Clods

Small soil clods on the soil surface are usually desirable to help prevent wind erosion and minimize soil crusting following a light rain or irrigation; however, clods at seed level or below are usually detrimental. Clods around the seed reduce seed-soil contact and reduce the ability of moisture to transfer from the soil to the seed to initiate germination. Tillage can break up clods or reduce clod size to improve the seedbed; however, once clods become dry and hard, it is difficult to restore the seedbed. When possible, it is better to avoid making the clods in the first place than to try to improve a cloddy seedbed. Clods are eas-

**Figure 5.5**

Depiction of soil condition following deep tillage made in the fall, over-winter freeze-thaw and wetting-drying cycles, and a single, shallow, non-inverting tillage made just before planting. Result is ‘consolidated’ soil, good tilth, few clods, retention of moisture, and good potential to move moisture vertically.



*Fall tillage should leave the soil relatively firm with medium clods and small ridges on the surface to minimize erosion from wind.*

ily made when moist, firm, soil is sliced and inverted and left to dry in a loose, clumpy, surface. This often happens with an implement such as a disk, moldboard plow, or “C” tine harrow. Wind, intense sunlight, and high air temperatures further “bake” the clods. Use an implement that does not invert the soil or bring fresh, moist, soil to the surface to form clods.

## Tillage Considerations: Less Is Better — Utilize Mother Nature

Most soil problems, including clods, compaction, soil crusting, and lack of good tilth, are caused by or at least aggravated by tillage and traffic. In most soils, the best seedbed for sugarbeet is developed by Mother Nature’s actions over winter. Intervention with tillage, particularly aggressive tillage in the spring just before planting, only makes the seedbed worse. These principles have been proven by tillage research in Europe and the United States and verified by successful production systems developed by sugarbeet producers.

Deep tillage in the fall to alleviate any soil compaction and freeze-thaw and wet-dry cycles over winter will provide an optimum seedbed for spring planting. Fall tillage should leave the soil relatively firm and the surface with only medium clods and small ridges to reduce soil erosion over winter. Any spring tillage should be shallow and non-inverting immediately prior to planting to accommodate accurate depth control with the sugarbeet planter (*Figure 5.5*).

In contrast, primary tillage with a moldboard plow or deep chisel in the spring will create clods and discontinuity within the tilled zone. Additional secondary tillage to break up the clods and firm the soil will just create smaller clods, lose soil moisture, and further degrade soil structure. Intensive secondary tillage in the spring reduces soil aggregate size which worsens soil crusting (*Figure 5.4*). Design sugarbeet tillage systems that minimize the number of, the depth of, and the intensity of spring tillage operations.

**Figure 5.6**  
German-made BBG “precision tillage” implement used for preparing a seedbed for sugarbeets.





**Figure 5.7**

European style “precision tillage” implement used for making a seedbed for sugarbeets, Kongsilde model ‘Germinator’.

## Successful Tillage Systems

**S**ugarbeet growers have used many different tillage systems to produce successful crops. The following tillage system examples have specific features that address particular tillage issues.

### European Tillage System

As in the United States, there are many tillage systems used in Europe, however, one system has evolved from considerable research and practical application to enhance seed germination and a healthy plant. With this system soil is moldboard plowed in the fall, winter, or early spring to allow frequent freeze-thaw cycles before final seedbed preparation and planting. The plow must be set and operated to give a level, uniform, surface. A packer is pulled behind the plow to leave the surface level but with small clods and small ridges to prevent soil erosion. Packer wheels are designed for specific soil types. Plowing alleviates soil compaction and buries residue and weed seed. Natural cycles of freeze-thaw and wet-dry make a very good soil tilth, particularly near the surface. The only other tillage operation used in this system is one pass with a “precision tillage” implement. This operation occurs immediately (less than a half day) ahead of the planter.

Many European manufacturers make versions of this precision tillage implement (*Figures 5.6 and 5.7*), all of which have similar characteristics. There is a cage-type rolling basket in front which loosens the soil, breaking the soil crust and clods. Next is a leveling bar used to level any high ridges; it is not intended to engage soil for its full width. The focal point of the implement is the configuration of four or five rows of closely spaced (2 inches from center to center, looking from front or rear), narrow (1 inch) vertical tines. The tines are narrow and vertical to facilitate soil stirring in the horizontal direction but cause little soil inversion. This allows moist soil to stay at seed depth, and keeps the dry, cloddy soil on the surface (*Figure 5.5*). The tines are intended to operate very shallow, preferably 1 to 2 inches deep. This requires level plowing and minimal tractor tire tracks with high floatation tires. The front and rear baskets break clods and serve as depth control for the tines. Following the tines are two rolling baskets with horizontal rod or bar members that continue to break clods and firm the soil without using heavy packing rollers. Last is a row of small diameter steel tines that just touch the soil surface to bring clods to the surface. The soil



**Table 5.1**

Comparison of final field emergence of sugarbeet planted into eight tillage systems in a University of Nebraska study. The percent emergence values are an average of results from an early season planting date and a late season planting date, both averaged over two years, 1995 and 1996. The previous crop was dry edible beans. Generally, among the four plantings, there were larger differences in final field emergence among systems when soil moisture was low, and smaller differences when soil moisture was high.

System name	Tillage system description	No. of tillage operations	Final field emergence (%)
Spring plow, roller harrow twice	In spring, disk ridges made for wind erosion protection, moldboard plow with trailing packer, roller harrow twice.	4	67
Spring plow, BBG* once	In early spring, moldboard plow with trailing packer, one pass of BBG* implement immediately before planting.	2	76
Modified ridge	In fall, form firm ridges. Remove top of ridge with planter and plant directly on ridge.	1	72
No plow, no spring tillage	Leave soil surface relatively level in fall after bean harvest. Plant without any spring tillage.	0	69
No plow, BBG* once	Leave soil surface relatively level in fall after bean harvest. One pass of BBG* implement immediately before planting.	1	78
No plow, double disk	Disk twice in spring.	2	66
Plow-plant	In spring, disk ridges made for wind erosion protection. Two days before planting, moldboard plow with trailing packer. No other tillage.	2	65
Fall plow, BBG* once	In fall, moldboard plow with trailing packer, one pass of BBG* implement immediately before planting.	2	77
		<i>lsd (p=0.05)</i>	3
*The BBG is a German-made secondary tillage implement designed for making a seedbed for sugarbeets. ( <i>Figure 5.6</i> )			

surface is very firm to the feel when walking on the field. The planter follows as soon as possible to “seal” in the moisture. This tillage system provided high sugarbeet emergence when compared to six other tillage systems in a recent University of Nebraska research project (*Table 5.1*).

### Disked Corn Stalk System

On sandy soils prone to erosion by wind, growers with a center pivot irrigation system and a well can use a field previously cropped to corn harvested for grain to successfully grow sugarbeet. Soil compaction during the previous corn crop must be avoided since there will be no deep tillage prior to the sugarbeet crop. Stalks can be grazed or simply disked. If the stalks have been grazed, two disking operations will usually be adequate to break the stalks into short lengths and leave 25-35 percent surface residue, adequate to prevent soil erosion in most cases. If the stalks have not been grazed, three passes with a disk will probably be required, or stalks can be shredded before disking. The goal is to leave at least 25 percent surface residue to control erosion, but not more than about



35 percent surface cover to complicate planting, emergence, or cultivating. A planter capable of handling corn residue is required, and two or three irrigations may be needed for good emergence.

### Fall Bed System

This system minimizes field operations when fall roughening is required to prevent soil erosion and creates an ideal seedbed for spring planting. This system can be used after dry edible bean or a similar crop that leaves very little surface residue following harvest. If soil compaction is present or suspected, an in-row ripper should precede or accompany the bedding operation. The bedder should create soil ridges or beds that are relatively short (a maximum of 3-5 inches above the bottom of the adjacent furrows), firm when walking on the bed top, and have mini-ridges and/or clods on the top surface to control soil erosion until planting. These beds will preserve soil moisture and will accommodate planting and cultivating operations. Herbicides can be broadcast applied and incorporated on top of the bed with an implement such as a Schmizer roller or a machine with two or more rolling baskets without tines. These rolling implements will vigorously incorporate the bed top without moving too much soil and accompanying herbicide off the center of the bed where it is needed for weed control. The beds are ready to plant and should be planted as soon after herbicide incorporation as possible. If incorporation is not needed, a similar operation may be needed to condition the bed surface. If weed growth has started, a herbicide may be required.

### Controlled Traffic System

This system is useful if soil compaction is a concern and field operations can be minimized. It applies best if there is not a large amount of crop residue on the surface and the soil surface is relatively level. Tillage consists of one pass with an implement (*Figure 5.2*) having in-row ripper shanks accompanied by angled disks to close the shank mark, followed by a rolling basket to firm the soil for the planter. The rolling basket could also be used to incorporate a herbicide. A bedder could be included with the implement or follow the implement. Advantages of this type of system are that there will be no tire tracks over the row, and the number of tillage operations can be minimized.

## Tillage Tracks and Tractor Tire Tracks

**F**requently, patterns or “tracks” can be seen at an angle across the rows of a sugarbeet field in the early stages of crop development (*Figure 5.8* and *Figure 5.9*). These tracks match the pattern of the tractor tires and/or some feature of the tillage implement. The first impression is often to think this is soil compaction. In fact, there may be soil compaction associated with these tracks; however, in the very early stages of plant emergence and growth there is a more serious problem of low, slow, or late emergence in the tire tracks created during tillage.

**Figure 5.8**  
Inconsistent sugarbeet  
stand caused by deep  
tractor tire tracks.



**Figure 5.9**  
Tillage tracks in a crop near  
Scottsbluff, Nebraska caused  
by deep tractor tire tracks.



### **Cause of Tillage Tracks and Tractor Tire Tracks**

Tillage for sugarbeet often includes moldboard plowing, ripping, or deep disking or chiseling. These operations leave the soil loose and soft. Subsequent operations for chemical or fertilizer application or secondary tillage operations often create tractor or implement tire tracks that are 4-6 inches deep in the soft soil. If the tillage implement is operated deep enough, the tire tracks will appear to be “erased,” but what really happens in these tire tracks during the tillage operation? Picture tire tracks made by the tractor rear or front tires. Fertilizer or herbicide is often broadcast applied to the field ahead of the secondary tillage implement, or herbicide may be applied at the front of a tillage implement such as a roller harrow. As the tillage implement operates through the tractor tire tracks, consider what soil is moving into these depressions in the soil. First, the fertilizer spread in a previous operation or the herbicide being applied at the front of this implement is at the bottom of the tractor tire track, already 4-6 inches deep compared to the adjacent soil surface. Second, if the tire tracks are this deep, there is very likely some level of soil compaction in these tire tracks and extending at least several inches below, perhaps as much as 6-10 inches.

Third, as the implement “closes” the tire tracks there will be a movement of soil into the tracks from the adjacent soil surface. Dry soil, clods, and fertilizer or herbicide applied to the adjacent surface tends to move into the tracks. This creates the potential for a concentration of dry soil, clods, and any fertilizer or herbicide applied to the soil surface in these tire tracks. Fourth, depending on whether the tillage implement was deep enough or intensive enough, there may still be a layer of compacted soil below the tire track.

Deep tire tracks often will have several negative impacts on the following sugarbeet crop:

- The relatively high proportion of dry soil and clods that have been moved into the tracks decreases emergence. This is the effect that causes the patterns across the field — decreased emergence. The condition is worsened when irrigation is not used for emergence.
- The relatively high concentration of any nitrogen fertilizer or herbicide that was created when surface soil was moved into the tire tracks can decrease emergence or plant vigor.
- If the bottom surface of the tire track was not aggressively tilled, this surface will probably become a layer of compacted soil. As the crop roots reach this layer, root sprangling and reduced yield will likely result.

### Minimize Tillage and Tractor Tire Tracks

Tillage and tractor tire tracks reduce sugarbeet yield and can be avoided. Some combination of the following techniques will eliminate the problem in almost all circumstances:

- Increase flotation
- Minimize tractor ballast
- Adopt controlled traffic cropping systems
- Use a soil firming implement

### Increase Flotation

This can be done with low inflation pressure radial tires and with tracks or belts. The key is to increase the contact area between the tire or track and the soil surface sufficiently so the tire does not penetrate into the soil for more than 1 or 2 inches maximum, or to decrease the weight of the tractor. The effect is to reduce the contact pressure between the tire or track and the soil to a level where deep tracks are not made in the soft soil. There are two very general, but instructive, guidelines that apply.

**Rule 1:** If the pressure of the tire or track against the soil surface is less than approximately 10 psi, there is little chance for deep tire tracks or soil compaction. If this contact pressure is greater than approximately 25 psi, deep tire tracks and soil compaction are likely. If the soil is very soft, wet, and loose, contact pressures as low as 15 psi can cause deep tire tracks and soil compaction. To relate these soil contact pressure values to flotation with radial tires, use *Rule 2*.

**Rule 2:** Soil contact pressure will be approximately 2 psi higher than the inflation pressure in a correctly inflated radial tire. For a rubber track or belt, the contact pressure can be estimated by dividing the total weight of the tractor by the total contact area of the tracks or belt.



The practical application of *Rule 2* for a tractor with radial tires is to weigh the front and rear of the tractor to determine the actual weight supported by the front tires and rear tires. Include any accessories such as chemical tanks with fluid, and any mounted implements in the raised position. Consult the “load and inflation tables” in a farm tractor tire handbook available from your tractor tire dealer. These tables will list the minimum inflation pressure for your tire size in single, dual, or triple configuration for the load carried per tire. This minimum inflation pressure is also the optimum pressure that will provide maximum floatation and maximum traction in most situations. The objective is to equip your tractor with the size and number of tires that permit a correct inflation pressure of 6 or 8 psi, if possible. Front tractor tires are often more of a floatation problem than rear tires. A radial tire that is correctly inflated at 6-8 psi or even 10 psi will have very good floatation and rarely create soil compaction. If the use of the tractor changes, review the tractor weight for a change in correct tire inflation. Check tire inflation often when using low inflation pressure levels.

**Figure 5.10**  
European tractor with  
floatation tires,  
front and rear.







**Figure 5.11**  
Examples of flotation  
tires available for  
U.S. tractors.

### ***Minimize Tractor Ballast***

Tire- (or track-) to-soil contact pressure also can be decreased by decreasing the weight of the tractor. Tractors are often ballasted according to a very general rule of 130 lb of tractor weight per drawbar horsepower. This value is too high if the tractor is being used at less than rated power or if the application is at a high field speed above approximately 5 mph. One of the implications is that if the implement can be appropriately operated at high field speeds, more of the tractor power can be utilized in the form of speed instead of pull or draft. The drawbar power required to pull an implement is a product of field speed and implement draft. Thus the same tractor power can be used to pull a wide implement at a low field speed or a narrow implement at a high field speed. A narrow implement pulled fast will require less draft and consequently less tractor ballast or total tractor weight. In turn, less tractor weight means lower tire inflation pressure and/or less chance for deep tire tracks or soil compaction.

### ***Adopt Controlled Traffic Cropping Systems***

The multiple problems caused by crop rows planted across tractor tire tracks can be avoided by using controlled traffic systems. There are many versions of controlled traffic, such as bed systems or in-row ripping, but the outcome is that tractor and implement tires pass between rows and not across rows during tillage and all cropping operations.

*Minimize tillage and tractor tracks by adjusting tire inflation and minimizing tractor ballast.*

### **Use a Soil Firming Implement**

The most severe tire track (and perhaps soil compaction) problems occur when the tractor and implement are operating in soft, loose soil, such as following a moldboard plow or deep disking. The problem can be minimized, although probably not eliminated, by pulling a soil firming implement behind the plow or disk. If this implement firms the soil and the soil “settles” naturally for a period of time before the next operation, the tractor tire tracks will not be as deep. The design of the soil firming implement is important for effective soil firming and for other practical cropping reasons. A smooth, drum-type roller is not efficient for soil firming and leaves the soil vulnerable to soil erosion. Better implements use soil firming elements such as wide bar rolling baskets or sharp angled, spaced packing wheels. The sharp angled, spaced packing wheels are designed to “wedge” the soil between the wheels to firm the upper soil layer, while leaving a ridged, cloddy surface that will resist soil erosion. In Europe this type of soil firming implement is often towed behind a moldboard plow for sugarbeet production (*Figure 5.12*).

**Figure 5.12**

European-type plow packer. This packer leaves a firm, level surface with small ridges and small clods.



*By Robert G. Wilson, John A. Smith, Stephen D. Miller,  
and K. James Fornstrom*

**W**ind erosion can occur when soils dry and small soil particles are moved by the wind. Wind erosion is usually more of a problem on sandy and peat soils. The drying out of the finely divided surface layers of these soils leaves them susceptible to wind erosion. Small soil particles are first detached and then moved by the wind. Once particles begin to move they have an abrasive action and dislodge other soil particles and intensify erosion. Dislodged soil particles bounce along the surface of the ground and may reach heights of a foot during saltation. Increased wind speed and smaller particle size can result in soil particles being suspended and carried by the wind.

## The Erosion Process

**F**actors affecting wind erosion are soil moisture content, wind velocity, soil surface roughness, soil characteristics, and the nature and orientation of vegetation or crop residues. Wind speeds of 12 miles per hour are sufficient to initiate soil erosion. As wind speeds increase above 12 miles per hour, the quantity of soil carried by the wind increases rapidly. A rough soil surface with large clods or ridges will reduce wind erosion. The presence of corn or small grain residues on the soil surface also will reduce soil movement. As the clay content of the soil increases, the stability of soil aggregates increases and wind erosion decreases. In contrast, as the sand content of the soil increases, aggregate stability decreases and soil movement by wind increases.

The sugarbeet crop is most susceptible to damage from wind erosion after planting and until the crop is big enough to begin shading the row. After emergence sugarbeet seedlings can easily be injured or killed by blowing soil particles. The problem is intensified if rain or irrigation reduces surface roughness, and as the soil dries it becomes susceptible to wind erosion. During the spring, wind speeds increase as weather fronts move from west to east across the intermountain sugarbeet growing region. Therefore the presence of sandy soils, frequent high intensity thunderstorms, and the absence of crop residues on the soil surface make wind erosion a serious threat to establishing the sugarbeet crop.

## Reducing Wind Erosion

**S**everal cultural methods can help reduce wind erosion. In the absence of crop residues, soil roughness and soil moisture content can reduce wind erosion. Also the planter can be equipped with tillage tools to roughen the soil surface adjacent to the crop row. This will generally reduce wind erosion until rainfall or irrigation reduce aggregate stability and clod size. As the soil dries, surface roughness must be reestablished by rotary hoeing, cultivating, or ditching the area between sugarbeet rows (*Figure 6.1*). Irrigation will temporarily stop wind erosion until the soil surface dries.



**Figure 6.1**  
Roughening the soil  
between sugarbeet rows.



## Crop Residues

Crop residues from the previous crop can be successfully utilized to provide wind and water erosion protection for the sugarbeet plant. Small grain stubble can be sprayed with a glyphosate product in the spring before sugarbeet planting to control emerged weeds. Sugarbeet can be planted directly into the stubble by equipping the planter with residue moving devices which remove the small grain residue directly over the crop row (*Figure 6.2*). The residue remaining between the sugarbeet rows will protect sugarbeet seedlings. When the crop is established this residue can be buried with cultivation. Sugarbeet also can be planted into corn residue that has been disked before planting. Again, the planter needs to be equipped with some type of residue moving devices to minimize corn residue directly over the row.

Corn and small grains produce sufficient residue after harvest to provide erosion protection during the winter and spring and for the following sugarbeet crop; however, other crops, particularly dry edible beans, do not provide enough residue after harvest to protect the soil or the following sugarbeet crop from wind erosion. Dry edible beans are harvested in early to mid-September. Cover crops of winter wheat or winter rye can be seeded immediately after bean harvest with a grain drill, or seed can be spread with a fertilizer spreader and incorporated into the soil with a shallow tillage operation. A disk drill with narrow row spacing will provide a level planting surface in the spring for the following sugarbeet crop. The seeding rate for either wheat or rye is usually 1 to 1.5 bu/acre. Rye will provide more top growth and better wind erosion protection than wheat early in the spring. The cover crop should be planted by September 15 to assure adequate soil protection over winter. If soil moisture is lacking at the time of seeding, sprinkler or furrow irrigation can be beneficial in improving cover crop density and growth.



## Cover Crops

A cover crop with sufficient growth will provide soil erosion protection during the fall, winter and spring. The fall seeded cover crop also can provide protection to a spring planted sugarbeet crop. Allow the cover crop to grow to a 3- to 5-inch height in the spring before killing with a glyphosate product like Roundup. Sugarbeet can then be planted directly into the standing cover crop residue, or strips can be tilled through the cover crop to provide a planting area for spring planted sugarbeet. An appropriate planter must be used for sugarbeet to obtain proper seed depth and to ensure that the cover crop residue is not punched into the seed furrow with the seed, creating inadequate seed-soil contact. A conventionally equipped, dedicated sugarbeet planter, such as a Milton or Deere 71 Flexi-Planter, will have difficulty placing sugarbeet seed at the proper depth and achieving good seed-soil contact in this cover crop situation.

Sugarbeet growers have devised an alternative practice for controlling fall planted broadcast or narrow-row cover crops while accommodating satisfactory performance of sugarbeet planters. When the cover crop reaches a height of 3-4 inches in the spring, narrow strips, approximately 12 inches wide, are sprayed and killed with herbicide. This spraying operation requires a band sprayer, straight rows and accurate “guess” rows. By sugarbeet planting time, the cover crop in these rows has died and sugarbeet can be planted without interference from the residue. The remaining cover crop in the interrow area must be sprayed with an appropriate herbicide immediately prior to sugarbeet planting or at least before any sugarbeet begin to emerge unless the sugarbeet is tolerant to the herbicide. This system provides both excellent wind erosion protection and good planter performance with traditional sugarbeet planters. Growers should be cautious because cutworms can be attracted to fall planted cereal cover crops and feed on sugarbeet seedlings as they emerge. Sugarbeet fields should be scouted early in the growing season for cutworms and treated with an insecticide if crop damage is observed (*see Chapter 9*).



**Figure 6.2**  
Planting sugarbeet into  
wheat stubble.

*Sugarbeets are especially vulnerable to soil erosion caused by wind until the crop is well established.*

An alternative to planting the cover crop with a grain drill or broadcasting the seed, is to plant the cover crop in defined rows to match the row spacing of the sugarbeet crop. The cover crop can be planted with a row crop planter, or with a grain drill which has appropriate openers shut off or raised (*Figure 6.3*). The cover crop rows must be planted straight using a marker to obtain accurate “guess row” width. The cover crop rows should be perpendicular to the prevailing wind. The row units for the cover crop planter or drill should be positioned so the tractor tires do not run over the soil where sugarbeet rows will be planted.

Seeding the cover crop in distinct rows provides a residue-free area for planting the spring row crop. Conventional sugarbeet planters can be used to plant the spring crop if the area between rows of cover crop is relatively level. An example of this technique would be to use a row crop planter to plant winter rye in 22-inch rows at the rate of 1 bu/acre in the fall after bean harvest. The following spring the cover crop should reach a height of 3 to 5 inches before being treated with Roundup at 1.5 to 2 pt/acre. Plant sugarbeet between the cover crop rows with a conventional sugarbeet planter. The cover crop provides early season protection for the developing seedlings until the sugarbeet are large

enough to protect themselves. The remaining cover crop could then be removed with cultivation.

**Figure 6.3**

Sugarbeet emerging between rows of wheat cover crop.



The timing of herbicide application to kill the cover crop is critical. The cover crop must be allowed to grow tall enough to provide adequate protection for both the soil and the crop to be planted. If allowed to grow too large, the cover crop will compete with the spring planted crop for soil moisture and may be more difficult to control. Rain or wind can delay herbicide application beyond the planned date. If a nonselective herbicide is used to kill the cover crop, it must be applied before any of the spring planted crop begins to emerge.





**Figure 6.4**  
Sugarbeet emerging  
in a spring seeded  
oat cover crop.

Spring planted sugarbeet on coarse textured soils can be injured by blowing soil particles. A spring planted cover crop can provide early season protection for sugarbeet until the crop is established (*Figure 6.4*). The seedbed can be prepared conventionally and barley or oats seeded at the rate of one bushel per acre with a row crop planter in March or early April. (*Figure 6.5*). Most row crop planters can be used to seed the cover crop in rows spaced far enough apart to facilitate the planting of sugarbeet in mid to late April. To prevent compaction over the sugarbeet row, the hitch attachment on the cover crop planter should be moved one-half row width on the planter frame so the tractor tires are in line with the cover crop rows rather than where the sugarbeet rows will be.

This spring seeded cover crop also could be planted in narrow rows with a disk drill. The resulting surface must be relatively level to allow planting directly into the growing cover crop without further tillage.

The cover crop should have emerged and begun to grow before sugarbeet are planted. Most conventional sugarbeet planters will perform satisfactorily in either wide or narrow rows if the surface between cover crop rows was left relatively level after cover crop planting. When the cover crop reaches a height of 6 to 8 inches if planted in wide rows, or 3 to 5 inches if drilled in narrow rows, it should be treated with an approved graminicide, such as Assure II or Select, appropriate for the crop being grown. The cover crop will provide early season protection for the establishing crop and can be killed before it becomes too large and begins to compete with the crop. When the sugarbeet is sufficiently large, the cover crop can be removed with cultivation.

**Figure 6.5**  
Sugarbeet emerging  
in a spring seeded oat  
cover crop planted in rows.



Cover crop systems are very effective for sugarbeet production. Properly managed, these systems minimize spring tillage, eliminate the need for emergency soil roughening, and will help assure a good sugarbeet stand. Producers who use cover crop systems offer the following five keys for success:

1. The cover crop must attain sufficient growth in the fall. This means early planting (by September 15) and irrigation as needed.
2. Careful attention should be paid to timing of herbicide application to kill the cover crop in the spring. If it's applied too early, there will not be enough cover; if it's applied too late, there will be too much competition with the sugarbeet crop for soil moisture, fertility, and sunlight.
3. Correct seed depth control and complete seed to soil contact should be ensured. Residue or an irregular soil surface must not interfere with planting sugarbeet.
4. Irrigation to establish the cover crop in the fall and to establish the sugarbeet crop in the spring will be essential. This is easiest with a well-supplied center pivot.
5. Be prepared to deal with an increased risk of early season cutworm problems.



*By C. Dean Yonts, John A. Smith and Robert G. Wilson*

## Planting Date

The selection of an optimum planting date can be an important step in maximizing sugarbeet yield. The primary factors to consider when determining when to start planting sugarbeet include:

- 1) total number of acres being planted;
- 2) time required to plant an acre;
- 3) probability of precipitation that would limit field work; and
- 4) probability of freeze that would damage young plants.

Based on research conducted by the universities of Nebraska and Wyoming, two factors, aside from cultural practices, were identified as the primary influences on sugarbeet germination and emergence: soil moisture and soil temperature. Soil moisture was found to be the critical factor in determining how *many* plants will germinate and emerge. Soil temperature dictates how *fast* sugarbeet plants will germinate and emerge. Other factors such as planting depth and physical impedance will be discussed later in this chapter.

The planting schedule can be slowed by wet weather and is a concern for all producers. Growers with fewer than 100 acres will likely need four to five days to plant. For larger growers with approximately 500 acres, planting time is increased, but the use of larger equipment should still allow planting to occur within about two weeks. Of course, the key to being able to finish planting on schedule is to have good planting weather. Certainly, it is understood that differences in soil type make a difference. For some, a 0.5-inch rain is a one- to two-day delay, but for others it can be a four- to five-day delay.

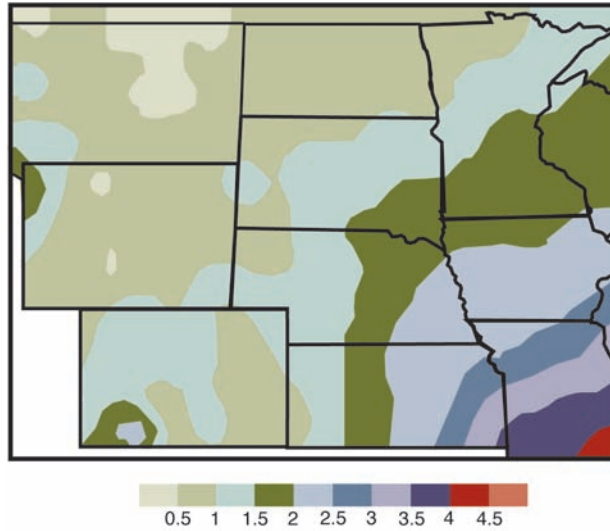
As spring planting is delayed into late April or May, the likelihood of precipitation increases. Thirty-year monthly average precipitation for March, April and May is shown in *Figures 7.1-7.3* for the Central High Plains sugarbeet growing region. Precipitation ranges from 0.5 to 1.0 inch in most areas in March and 1.0 to 2.0 inches in April. In May, the variation in precipitation increases among the sugarbeet planting regions as does total precipitation. Precipitation in May varies from a low of 1.5 to 2.0 inches in northern Wyoming to as high as 3.0 to 3.5 inches in the Nebraska Panhandle.

Soil temperature, like precipitation, increases with later planting dates as a result of day length and the increase in solar radiation. Other factors such as surface residue, irrigation, or soil color also affect soil temperature, but none influences soil temperature as much as the increase in solar radiation absorbed by the soil with each passing day.

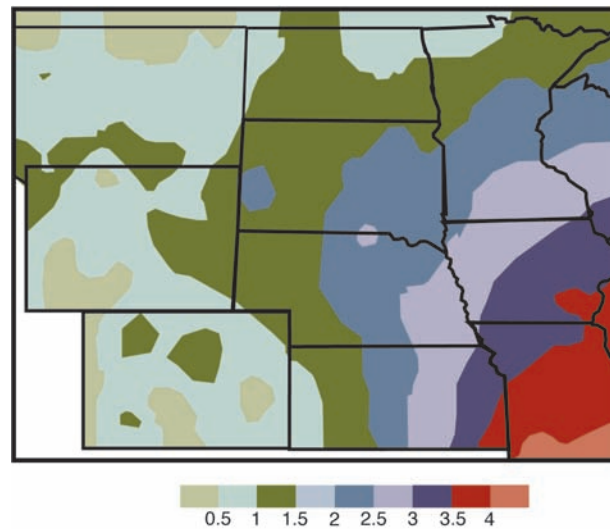
Studies conducted in Nebraska and Wyoming were designed to identify the role of soil temperature and soil moisture in sugarbeet germination and emergence. It was determined that to reach a 50 percent emergence level, approximately 85 soil heat units were required. Heat units are accumulated every day that the soil temperature is above 40° F. High soil temperatures accumulate heat

*Soil moisture dictates how many plants will emerge; soil temperature dictates how fast they will emerge.*

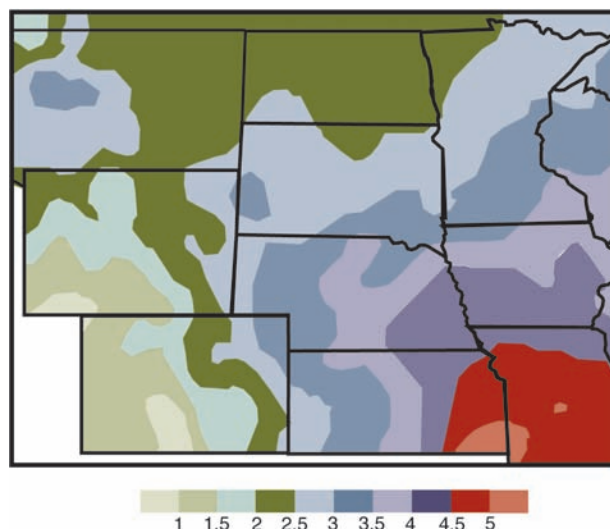
**Figure 7.1**  
Average March  
precipitation  
in inches for the  
Central High Plains.  
(Based on University of  
Nebraska High Plains  
Climate Center data.)



**Figure 7.2**  
Average April  
precipitation  
in inches for the  
Central High Plains.  
(Based on University of  
Nebraska High Plains  
Climate Center data.)

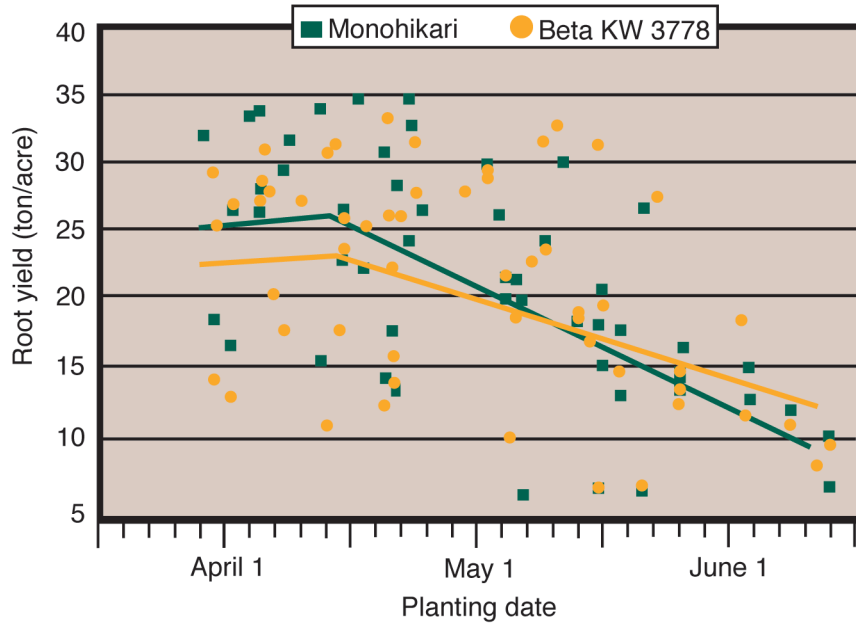


**Figure 7.3**  
Average May  
precipitation  
in inches for the  
Central High Plains.  
(Based on University of  
Nebraska High Plains  
Climate Center data.)



units faster than low soil temperatures. For example, if the average soil temperature was 50° F for one day, 10 soil heat units would be accumulated. Using average temperature in a sugarbeet emergence-temperature model developed at the University of Wyoming, sugarbeet planted in Scottsbluff on April 1 would require 20 days to accumulate approximately 85 soil heat units. If planting were delayed to April 15, it would take only 10 days to reach 85 soil heat units because of increased temperature and day length. This means sugarbeet planted on April 1 would reach a 50 percent emergence level on April 20. Sugarbeet planted on April 15 would reach the 50 percent emergence level on April 25. In this example, the delay in planting was 15 days, yet the delay in germination and emergence was actually only five days. Heat unit accumulation will vary for the different growing regions, but the result will be similar. Planting in late March and early April will extend the actual growing season on the calendar, but the accumulation of heat units is significantly slower than when compared to a later planting date.

The most recent study to determine optimum planting date was based on trials conducted at four locations in the Nebraska Panhandle from 1991 to 1993 (*Figure 7.4*). Yield varied significantly between years even though the planting date was the same. The results from this study indicate that the greatest yield was obtained from planting on or near April 15. Yields decreased the further planting dates were from April 15. These findings are similar to those found in studies completed in the 1940s and 1950s in Wyoming and Nebraska. In



**Figure 7.4**

Yield response from two sugarbeet varieties at different planting dates. Planting on or near April 15 is recommended to provide the greatest yield return and reduce risk.

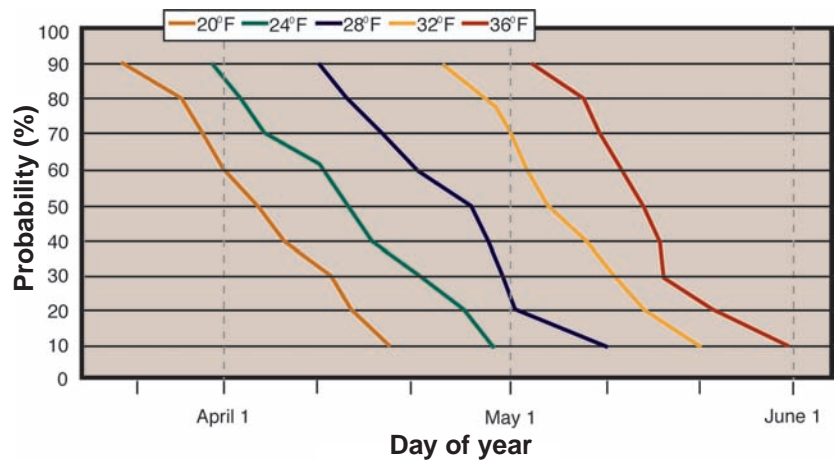
those studies planting in late March or early April did not increase yields compared to planting in mid April. Remember that the risks due to adverse climatic conditions are greater for earlier planted sugarbeet than for later planted sugarbeet. Also, as noted earlier, germination and emergence will occur much faster later in the spring as soil temperatures warm. Faster emergence reduces the time when seedlings are most vulnerable to damage.

Late spring freezes are common in the Central High Plains and can injure sugarbeet. Sugarbeet are sensitive to temperatures of 28°F or below when the hypocotyl is bent, pulling the cotyledons through the soil and until the crop has developed true leaves. The probabilities of receiving freezing temperatures during late March through June 1 for locations in Colorado, Montana, Nebraska, and Wyoming are presented in *Figures 7.5 to 7.8*, respectively. There is a 20 percent, 20 percent, 50 percent, and 45 percent probability that air temperature will be below 28°F after May 1 at Sterling, Colorado, Billings, Montana, Mitchell, Nebraska, and Powell, Wyoming, respectively. By delaying planting until April 15, sugarbeet emergence is delayed and the risk from frost damage is reduced.

The following planting date strategy is recommended, given: soil heat units are accumulated at a faster rate for later planting dates; later planting dates mean shorter germination times; probability for freezing temperatures decreases with later planting dates; and research indicates little advantage to early April planting. The target to complete planting should be approximately April 25. Larger producers may need to begin slightly earlier and end later and planting dates may need to be adjusted for higher elevations, but the optimum planting date for most of the Colorado, Montana, Nebraska, and Wyoming growing region would be April 15.

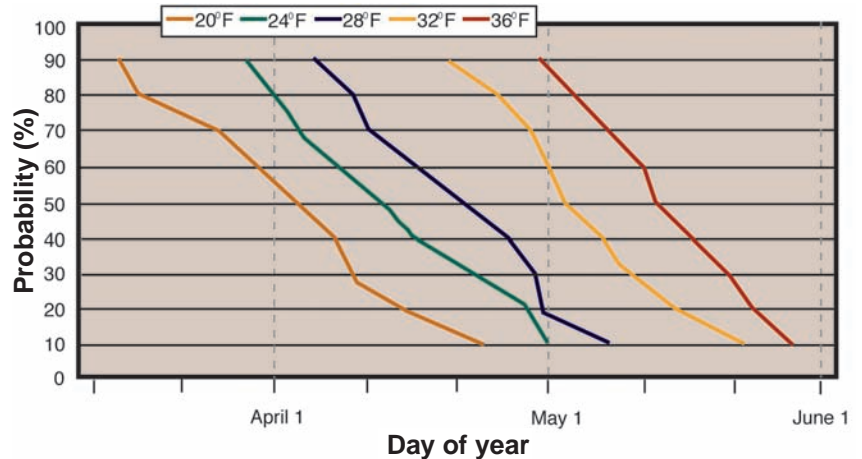
**Figure 7.5**

Probability of temperature below threshold occurring later than given date at Sterling, Colorado.  
(Based on University of Nebraska High Plains Climate Center data for 8/1/1948 to 7/31/2000.)



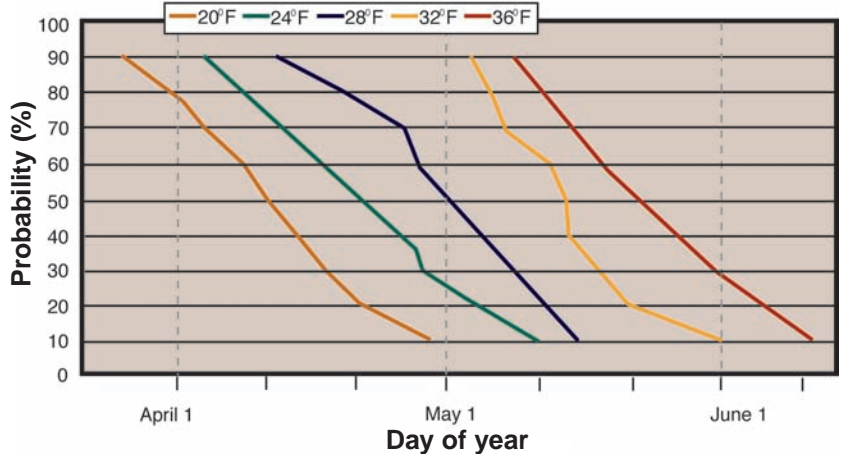
**Figure 7.6**

Probability of temperature below threshold occurring later than given date at Billings, Montana.  
(Based on University of Nebraska High Plains Climate Center data for 7/1/1948 to 12/31/2000.)



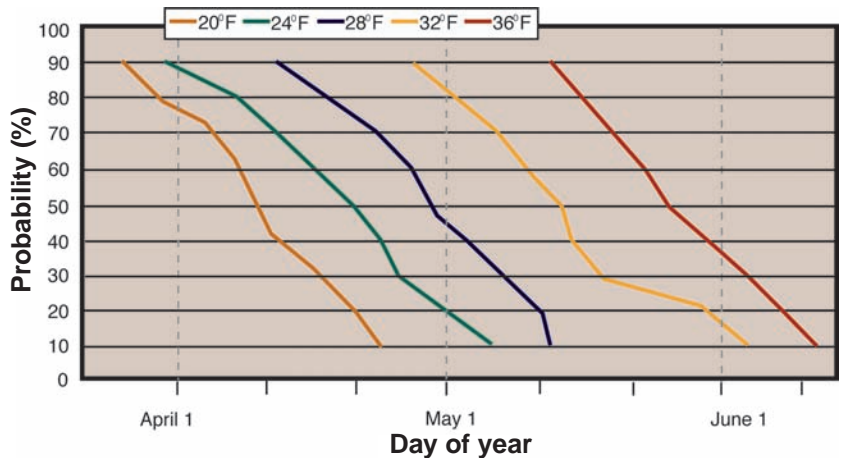
**Figure 7.7**

Probability of temperature below threshold occurring later than given date at Mitchell, Nebraska.  
(Based on University of Nebraska High Plains Climate Center data for 6/1/1909 to 4/30/1999.)



**Figure 7.8**

Probability of temperature below threshold occurring later than given date at Powell, Wyoming.  
(Based on University of Nebraska High Plains Climate Center data for 1/1/1915 to 3/31/1981.)





## Replanting

**B**efore deciding whether to tear out a stand of sugarbeet and replant, carefully evaluate the field. If the plants have been damaged due to wind, freezing temperature or hail, give the plants a few days to recover before determining the plant population. To accurately determine the plant population, place flags within a single row, 100 feet apart. Do this at a minimum of five locations in the field. Take stand counts between the flags, then use the information in *Table 7.1* to determine the plant population in your field.

**Table 7.1**

Plant population based on stand count measurements for making replanting decisions.

Plants per 100 feet of row	Plants per acre 22-inch row spacing	Plants per acre 30-inch row spacing
170	40,000	30,000
150	35,500	26,000
130	31,000	22,500
110	26,000	19,000
90	21,500	15,500
70	16,500	12,000

In 30-inch rows, 100 plants per 100 feet of row is slightly over 17,000 plants per acre. This is probably a minimum plant population that would be desired before tearing out the sugarbeet to replant. In 22-inch rows, having only 70 plants per 100 feet of row will result in slightly less than 17,000 plants per acre. See the plant population section later in this chapter for guidelines on acceptable populations.

If your plant population has been reduced, it becomes even more important to protect the young plants from any additional pest pressure. Return every one to two days to recount those same flagged areas. This gives you an immediate way to compare what is happening with individual plants and whether the plant population is changing.

Another aspect to consider when assessing a somewhat reduced plant population is what kind of weed pressure will result. This depends to some extent on field history, but when the plant canopy is reduced either due to late planting or plant loss, soil will be exposed for longer times, resulting in additional weed seed germination. Additional weed control will be necessary, but herbicides cannot be applied until sugarbeet have recovered from any injury due to freezing temperature, hail or pest pressure.

Replanting will likely mean less soil moisture for germination with warmer temperatures and dry winds putting germinating seedlings under water stress almost immediately after planting. This will likely mean that achieving the target plant population will be more difficult even if irrigation is used. Planting later in the season and obtaining a lower plant population will likely mean reduced yield.

If replanting is necessary, some consideration should be given to the performance of different varieties late in the growing season. In *Figure 7.4*, Monohikari performed better compared to Beta KW3778 early in the season, but Beta KW3778 performed better than Monohikari when it was planted later in the growing season. There is not much information on late planting and the performance of different varieties. This information is likely available through grower experience in a given area.

Based on past research, replanting in mid to late May could reduce sugar production by 25 percent to 50 percent of the expected yield respectively, compared to a mid April initial planting date. The decision to replant in May should consider not only the cost of replanting and the expected yield loss, but also what options are available based on herbicides used and the yield potential from planting an alternative crop.

*Replanting  
sugarbeet in mid  
May can reduce  
sugar production  
by 25%, and in late  
May, by 50%.*

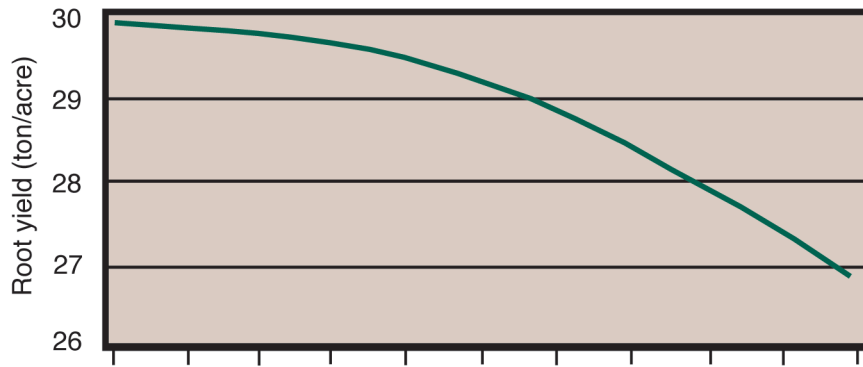
## Row Width

The question of wide vs. narrow row width has probably been researched and discussed in the coffee shop longer than any other cultural operation used in growing sugarbeet. Of course, the definition of wide or narrow depends on the time. In the mid 1900s, narrow was considered to be 16-18 inches while wide rows were considered to be 22-24 inches. Now, when we define wide and narrow, narrow is 22 inches and wide is 30 inches. Each time producers choose to increase row width, either from 16 to 22 inches or 22 to 30 inches, it is to fit current farm machinery. Whenever wider row width became the accepted practice, research was conducted to determine the impact on yield. Each time research came to the same conclusion: sugarbeet grown on narrower rows had better yield than sugarbeet grown in wider rows. In fact, in over 30 different research trials, all conducted to compare different row widths, the results indicated that narrow rows (18-22 inches wide) produced an average of 590 pounds of sugar pre acre more than did wide rows (23-30 inches wide).

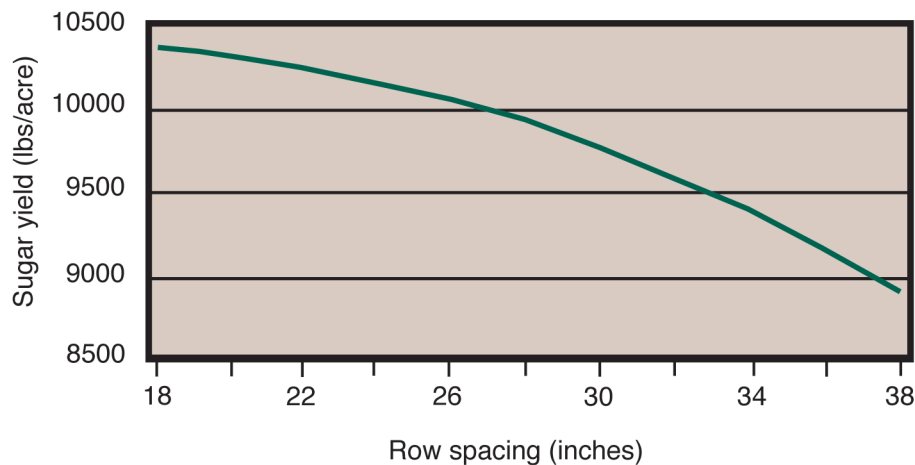
During this same time the question of row width also was being considered in Europe. Similar discussions occurred and the results were the same. Narrow rows mean higher yield. Today in Europe, however, sugarbeet considered to be grown in wide rows are in 22-inch rows. More commonly, sugarbeet are grown in 18-inch rows and there is a trend to 16-inch rows. Why? Because yield increases with narrower row width.

In one of the more recent studies in the Central High Plains, the University of Nebraska compared different row widths and found changing row spacing from 22 to 30 inches reduced root yield approximately one ton per acre and sugar yield, 500 pounds per acre. Results from this Nebraska test and previous research trials to compare different row widths are reflected in *Figure 7.9*.

The ability to more easily use new farm equipment with wider tires often was cited as the reason to move from narrow to wide rows. With the recent introduction of narrow width radial tires, the option of growing crops in narrower rows becomes more functional. Sugarbeet are not the only crop with a yield advantage with narrower rows. Corn has been shown to have yield advantages when grown in 22-inch rows compared to 30-inch rows.



**Figure 7.9a**  
Effect on root yield from changing row spacing.



**Figure 7.9b**  
Effect on sugar yield from changing row spacing.

The response of other crops to narrow rows is important because whatever row width is chosen, it will likely be chosen for all crops grown. In the Central High Plains the primary row crops include sugarbeet, corn and dry bean. Other crops grown in the area such as alfalfa and spring grains are not row-width dependent.

The advantages of having several row crops all grown in the same row width is obvious — there is no need to change wheel spacings on tractors, planters and cultivators and equipment can be used on several crops. One other factor that should be considered involves capturing the energy from the sun.

The sugarbeet is like a factory driven by the sun's energy. As the leaves grow and intercept more of the solar radiation reaching the ground, this energy is converted into sugar production. When energy is plentiful, growth is good. When skies are cloudy, the energy is blocked and the growth slows. Because of a limited growing season, it is necessary to take advantage of as much of the sun's energy as possible. The most energy received from the sun occurs on the longest day of the year, June 21. If on June 21 sugarbeet leaves only partially cover the soil, some of the sun's energy is lost. It is important to have full canopy cover as early as possible, so the plant can capture as much solar energy as possible.

The question is, what does the sun's energy have to do with how wide rows are spaced? Sugarbeet planted in narrow rows can intercept more of the sun's energy earlier by closing the space between the rows faster. Sugarbeet planted in 30-inch rows may never completely close the row and that energy is lost



to growing weeds between the rows the entire growing season. Since more sunlight reaches the soil when the crop is planted in wider spaced rows, soil temperature increases and enhances the development of certain root diseases, nematodes and weeds. The sun's energy is used to produce sugar. The more of the sun's energy that can be used, the greater the sugarbeet production (*Figure 7.10 a-c*).

**Figure 7.10a**

Sugarbeet grown in 22-inch rows produce 1-1.5 ton/acre more than sugarbeet grown in 30-inch rows.



**Figure 7.10b**

Sugarbeet grown in 22-inch rows capture more of the sun's energy for conversion into sugar.



**Figure 7.10c**

Late season weeds are more of a problem in 30-inch rows.

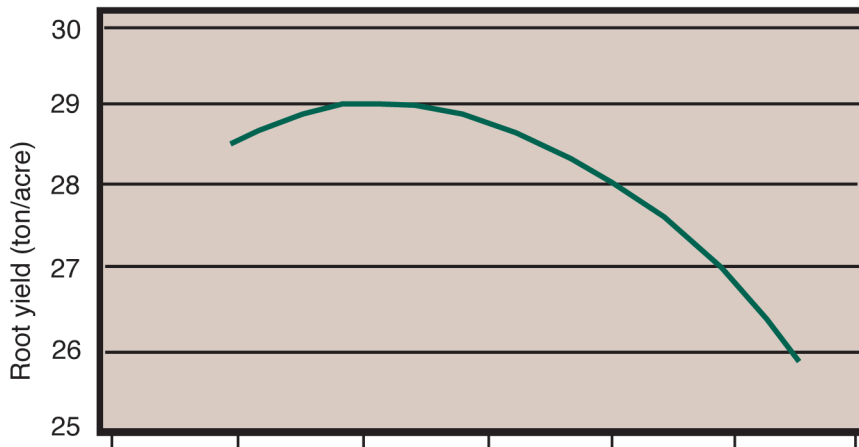




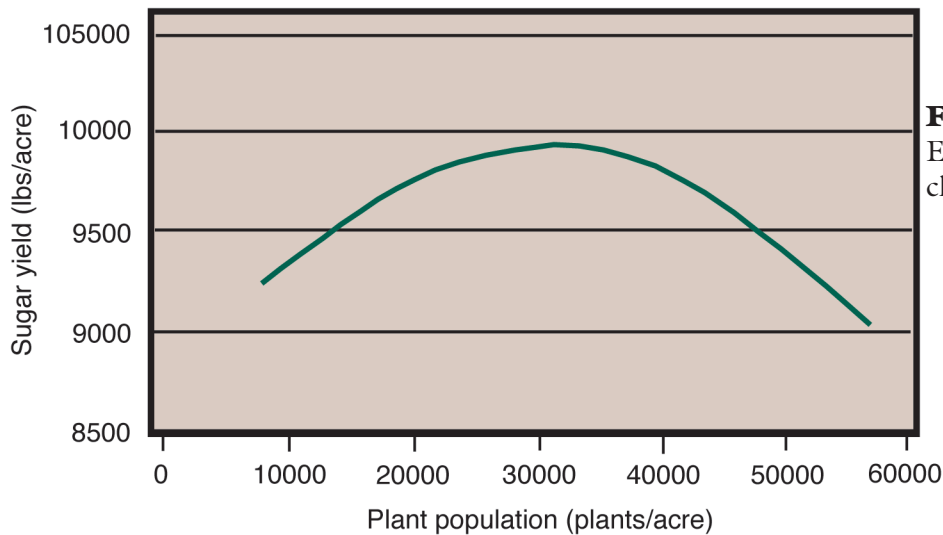
## Plant Population

Early research to define the best plant population concluded that increasing plant population resulted in higher root yield and/or higher sugar content. The influence of plant populations on yield was found to be the same over a wide range of climatic conditions. The most recent plant population experiments were done in Nebraska and compared five plant populations: 10,000, 16,000, 26,000, 41,000 and 60,000 plants per acre. Results from these trials indicated maximum sugar yields were obtained from plant populations of 30,000 to 40,000 plants per acre (*Figure 7.11 a-b*).

Achieving a high plant population becomes even more difficult in wider row widths. In-row spacing between sugarbeet plants becomes quite small in wider rows. Competition among plants forces a portion of the plants to die or simply not mature into a harvestable sugarbeet. Maintaining adequate plant populations becomes more of a challenge with 30-inch rows than with 22-inch rows.



**Figure 7.11a**  
Effect on root yield from changing plant populations.



**Figure 7.11b**  
Effect on sugar yield from changing plant populations.

*Measure sugarbeet stands at the six true leaf stage to assess the need for replanting or thinning.*

## Plant-to-Stand vs Thinning — What Seed Spacing?

There are several general “concepts” used to get the desired plant population of established sugarbeet plants. One is to plant many more seeds per acre than the desired number of plants per acre and then thin the emerged plants to the target plant population. An advantage of this system is that thinning can be adjusted to compensate for the actual emergence. Disadvantages include the cost of extra seed and the cost and management of thinning.

A second concept is plant-to-stand. In this case the grower must estimate the anticipated emergence and plant enough seeds per acre to compensate for those seeds that do not emerge or develop into established plants. Primary advantages for this system include lower cost for seed and no cost or management for thinning. A disadvantage is that unexpected weather or soil conditions can cause emergence to be different than estimated, and the established stand can be higher or lower than preferred.

Both “thinned” and “plant-to-stand” systems have been used for successful sugarbeet production. There are different input costs and different types of management involved for each system.

A third planting strategy might be called the “hybrid” system. It is often tempting for growers who have not had consistent plant emergence or who are not comfortable with estimating a percent emergence to determine seed spacing. The idea behind this system is to plant on the heavy side. If emergence is high then thin, but if emergence is low then don’t thin. At first glance this sounds like a fail-safe approach, but closer examination reveals a conceptual problem illustrated by the following example.

Suppose a grower uses 30-inch row spacing and would like to end up with about 35,000 plants per acre at the four true leaf stage of growth. Plant-to-stand logic might anticipate 65 percent emergence so the planter would be adjusted to a 4 1/4-inch average seed spacing. If emergence is 80 percent (very high), the resulting plant population would be 39,000 plants per acre which is still acceptable. If the emergence is 50 percent, the plant population would be 25,000 plants per acre, a little low but still acceptable. Between 50 percent and 80 percent emergence the plant population is okay. If emergence is below 50 percent, the plant population will be low and there is nothing the grower can do.

If this same grower decided to plant with the intent of thinning, an average seed spacing of 2 or 2 1/2 inches would be recommended. As long as emergence was above 40 percent, and assuming emergence was somewhat random without long gaps, there would still be enough plants to thin without dropping the final plant population too low. With a 2-inch seed spacing, an ideal plant spacing of 6 inches would give a final plant population of 35,000 plants per acre. Depending on which plants emerged, a spacing of 4 inches, 6 inches, or 8 inches down the row, but averaging 6 inches, would result in the correct final population. The important point is that the person or machine doing the thinning has a number of options mathematically and practically, to remove plants and end up with a good plant population and good spacing between individual plants.

Now, let's look at the "hybrid" system and assume the grower decided to plant somewhere between the spacings ordinarily used for plant-to-stand and for plant-to-thin. The grower decides to plant at a 3 1/2-inch spacing in a 30-inch row width. The grower's logic is if emergence is over 70 percent, then the field will be thinned. The practicality of thinning a 3 1/2-inch seed spacing to an acceptable plant spacing becomes questionable. If every other plant emerged in a 3 1/2-inch seed spacing, everything would be fine, but emergence is never that predictable. In some sections of the row, emerged plants will be spaced at 3 1/2 inches, 7 inches, 10 1/2 inches, or even wider. A spacing of 3 1/2 inches is too close for good plant development and good harvest so one plant should be removed whenever there is a spacing of 3 1/2 inches or less. This thinning operation will leave plants at a minimum spacing of 7 inches, with some spacings of 10 1/2 inches and greater. The final plant population after this thinning will likely be less than 20,000 plants/acre, even with very careful thinning.

The "hybrid" system with its "in between" seed spacing presents a problem for thinning if thinning is required. If emergence is very low, there will likely be long gaps within the row, reducing yield and encouraging weed growth. If emergence is high, thinning will be required. But thinning, whether manual, selective machine, or non-selective machine, will be left with few options to remove plants that will result in both the desired plant population and adequate spacing between individual plants. Most growers have found that choosing either an intentional thinning system, or an intentional plant-to-stand system, and applying good management for that particular system, will provide a more acceptable final plant stand than the "hybrid" system.

The plant population and seed spacing tables for 22-inch (*Table 7.2*) and 30-inch row spacings (*Table 7.3*) provide guidance for selecting a planter seed spacing. From previous field history and anticipated seedbed and soil moisture conditions, estimate field emergence, select a target established plant population, and read the associated seed spacing for your row spacing. When estimating future emergence, keep in mind that the average emergence in fields of sugarbeet growers in Nebraska, Colorado, and Wyoming is about 65 percent. Field emergence of 80 percent is very good, and an emergence of 90 percent is very rare.

## Depth of Planting

**S**ugarbeet emergence is influenced by soil moisture, soil temperature, aeration, and physical impedance. The influence of soil temperature and soil moisture on germination and emergence was discussed earlier in this chapter. Physical impedance relates to the distance seedlings move through the soil to emerge (planting depth), and the structure of the soil that the seedling has to move through.

Researchers at the universities of Wyoming and Nebraska have measured sugarbeet emergence at different planting depths. Wyoming compared 0.75-inch and 1.25-inch planting depths and found better emergence at the shallower depth. In a Nebraska study, 0.5-, 1.0-, 1.5- and 2.0-inch planting depths were compared. Both of the shallower depths, 0.5- and 1.0-inch, gave the best results. Based on these and similar studies, the optimum recommended depth for planting sugarbeet is 0.75-1.0 inch.

**Table 7.2**

Seed spacing, percent emergence, and plant population relationships for 22-inch row spacing.

Average Seed Spacing (inches)	Values in Table are Plant Populations (Plants/A) for 22-inch row spacing. Resulting From Combinations of Average Seed Spacing and Percent Field Emergence															
	Anticipated or Measured Field Emergence (%)															
	35	40	45	50	55	60	65	70	75	80	85	90	95	100		
2.0	49,900	57,000	64,200	71,300	78,400	85,500	92,700	99,800	106,900	114,000	121,200	128,300	135,400	142,600		
2.5	39,900	45,600	51,300	57,000	62,700	68,400	74,100	79,800	85,500	91,200	96,900	102,600	108,300	114,000		
3.0	33,300	38,000	42,800	47,500	52,300	57,000	61,800	66,500	71,300	76,000	80,800	85,500	90,300	95,000		
3.5	28,500	32,600	36,700	40,700	44,800	48,900	53,000	57,000	61,100	65,200	69,200	73,300	77,400	81,500		
4.0	24,900	28,500	32,100	35,600	39,200	42,800	46,300	49,900	53,500	57,000	60,600	64,200	67,700	71,300		
4.5	22,200	25,300	28,500	31,700	34,800	38,000	41,200	44,400	47,500	50,700	53,900	57,000	60,200	63,400		
5.0	20,000	22,800	25,700	28,500	31,400	34,200	37,100	39,900	42,800	45,600	48,500	51,300	54,200	57,000		
5.5	18,100	20,700	23,300	25,900	28,500	31,100	33,700	36,300	38,900	41,500	44,100	46,700	49,200	51,800		
6.0	16,600	19,000	21,400	23,800	26,100	28,500	30,900	33,300	35,600	38,000	40,400	42,800	45,100	47,500		
6.5	15,400	17,500	19,700	21,900	24,100	26,300	28,500	30,700	32,900	35,100	37,300	39,500	41,700	43,900		
7.0	14,300	16,300	18,300	20,400	22,400	24,400	26,500	28,500	30,500	32,600	34,600	36,700	38,700	40,700		
7.5	13,300	15,200	17,100	19,000	20,900	22,800	24,700	26,600	28,500	30,400	32,300	34,200	36,100	38,000		
8.0	12,500	14,300	16,000	17,800	19,600	21,400	23,200	24,900	26,700	28,500	30,300	32,100	33,900	35,600		
8.5	11,700	13,400	15,100	16,800	18,400	20,100	21,800	23,500	25,200	26,800	28,500	30,200	31,900	33,500		
9.0	11,100	12,700	14,300	15,800	17,400	19,000	20,600	22,200	23,800	25,300	26,900	28,500	30,100	31,700		
9.5	10,500	12,000	13,500	15,000	16,500	18,000	19,500	21,000	22,500	24,000	25,500	27,000	28,500	30,000		
10.0	10,000	11,400	12,800	14,300	15,700	17,100	18,500	20,000	21,400	22,800	24,200	25,700	27,100	28,500		
10.5	9,500	10,900	12,200	13,600	14,900	16,300	17,700	19,000	20,400	21,700	23,100	24,400	25,800	27,200		
11.0	9,100	10,400	11,700	13,000	14,300	15,600	16,800	18,100	19,400	20,700	22,000	23,300	24,600	25,900		
11.5	8,700	9,900	11,200	12,400	13,600	14,900	16,100	17,400	18,600	19,800	21,100	22,300	23,600	24,800		
12.0	8,300	9,500	10,700	11,900	13,100	14,300	15,400	16,600	17,800	19,000	20,200	21,400	22,600	23,800		

**Notes:**

Plant population values in red are seed spacing and field emergence combinations that will provide the highest yield.

Field emergence below 70 percent will result in large gaps causing reduced yield and increased weed pressure.

Field emergence above 90 percent is rare and very difficult to achieve.

Established plant populations in the range of 30,000 - 40,000 plants per acre will produce highest sugar yield.

Most fields in the Nebraska, Colorado, Wyoming region attain field emergence in the range of 55 percent to 75 percent.

Example — A 6.0-inch average seed spacing with a 70 percent field emergence will result in a stand of 33,300 plants per acre.



**Table 7.3**

Seed spacing, percent emergence, and plant population relationships for 30-inch row spacing.

Average Seed Spacing (inches)	Values in Table are Plant Populations (Plants/A) for 30-inch row spacing. Resulting From Combinations of Average Seed Spacing and Percent Field Emergence													
	Anticipated or Measured Field Emergence (%)													
	35	40	45	50	55	60	65	70	75	80	85	90	95	100
2.0	36,600	41,800	47,000	52,300	57,500	62,700	68,000	73,200	78,400	83,600	88,900	94,100	99,300	104,500
2.5	29,300	33,500	37,600	41,800	46,000	50,200	54,400	58,500	62,700	66,900	71,100	75,300	79,500	83,600
3.0	24,400	27,900	31,400	34,800	38,300	41,800	45,300	48,800	52,300	55,800	59,200	62,700	66,200	69,700
3.5	20,900	23,900	26,900	29,900	32,900	35,800	38,800	41,800	44,800	47,800	50,800	53,800	56,800	59,700
4.0	18,300	20,900	23,500	26,100	28,700	31,400	34,000	36,600	39,200	41,800	44,400	47,000	49,700	52,300
4.5	16,300	18,600	20,900	23,200	25,600	27,900	30,200	32,500	34,800	37,200	39,500	41,800	44,100	46,500
5.0	14,600	16,700	18,800	20,900	23,000	25,100	27,200	29,300	31,400	33,500	35,500	37,600	39,700	41,800
5.5	13,300	15,200	17,100	19,000	20,900	22,800	24,700	26,600	28,500	30,400	32,300	34,200	36,100	38,000
6.0	12,200	13,900	15,700	17,400	19,200	20,900	22,700	24,400	26,100	27,900	29,600	31,400	33,100	34,800
6.5	11,300	12,900	14,500	16,100	17,700	19,300	20,900	22,500	24,100	25,700	27,300	29,000	30,600	32,200
7.0	10,500	11,900	13,400	14,900	16,400	17,900	19,400	20,900	22,400	23,900	25,400	26,900	28,400	29,900
7.5	9,800	11,200	12,500	13,900	15,300	16,700	18,100	19,500	20,900	22,300	23,700	25,100	26,500	27,900
8.0	9,100	10,500	11,800	13,100	14,400	15,700	17,000	18,300	19,600	20,900	22,200	23,500	24,800	26,100
8.5	8,600	9,800	11,100	12,300	13,500	14,800	16,000	17,200	18,400	19,700	20,900	22,100	23,400	24,600
9.0	8,100	9,300	10,500	11,600	12,800	13,900	15,100	16,300	17,400	18,600	19,700	20,900	22,100	23,200
9.5	7,700	8,800	9,900	11,000	12,100	13,200	14,300	15,400	16,500	17,600	18,700	19,800	20,900	22,000
10.0	7,300	8,400	9,400	10,500	11,500	12,500	13,600	14,600	15,700	16,700	17,800	18,800	19,900	20,900

**Notes:**

Plant population values in red are seed spacing and field emergence combinations that will provide the highest yield.

Field emergence below 70 percent will result in large gaps causing reduced yield and increased weed pressure.

Field emergence above 90 percent is rare and very difficult to achieve.

Established plant populations in the range of 30,000 - 40,000 plants per acre will produce highest sugar yield.

Most fields in the Nebraska, Colorado, Wyoming region attain field emergence in the range of 55 percent to 75 percent.

Example — A 4.0-inch average seed spacing with a 70 percent field emergence will result in a stand of 36,600 plants per acre.

*A good stand of sugarbeet is critical. Later management and inputs cannot compensate for a bad start.*

If soil moisture is good, there may be a tendency to try to plant shallower in an attempt to get the plants up faster. Also, by planting shallow, the risk of having seedlings emerge through a thick crust is minimized; however, drying winds can quickly remove moisture from the top 0.5-inch of soil and quickly desiccate the seed or plant. At a 0.5-inch planting depth irrigation will likely be necessary until plants are established.

Sugarbeet injury from herbicides or insecticides applied at planting also can be influenced by planting depth. As the depth of planting is increased, emergence time and exposure of the emerging plant to pesticide-treated soil increases which in turn increases the potential for crop injury. From a crop injury standpoint, planting seed at depths greater than 1 inch is not desirable.

The decision to plant deeper than 1 inch is normally an attempt to place the seed into moist soil in times of limited soil moisture. Certainly, planting into a firm seedbed with adequate soil moisture is ideal, yet planting deeper to reach moist soil can be disastrous if planting is followed by rains and a crust is formed. Planting deeper than 1 inch forces the germinating seed to use much of its stored energy during emergence. Once emerged, little energy is available for early plant growth. Producers may describe the plants as appearing stunted. The plants may seem to sit in the soil and not grow, especially if emergence has been slow due to physical impedance.

Planting sugarbeet deeper than recommended in an attempt to reach moist soil should not be an acceptable alternative if irrigation is possible. At the same time, placing seed into moist soil is somewhat related to the type of seedbed that has been prepared. When planting on beds with dry soil conditions, some of the dry soil on the surface could be removed so seed can be placed in moist soil at the preferred depth. Remember, a bed formed in the fall will likely have better soil moisture conditions than one prepared just prior to planting.

If sugarbeet are planted without forming any beds or creating furrows, options are diminished. Moving dry soil to reach moist soil will be difficult because the seed will in effect be planted in the bottom of a small furrow. Any rain that occurs will accumulate in this furrow, taking with it fine soil particles. The soil conditions will be perfect for the formation of a crust directly over the seed row. Also, if planted on a flat field without any type of furrows, furrow irrigation for emergence will be extremely difficult.

If soil moisture is at a critical level and it is questionable how long the soil moisture will meet the needs of the germinating plant, it is best to plant at the recommended depth and plan for irrigation as soon as possible.

## Sugarbeet Planters

A good stand of sugarbeet plants is absolutely critical to a successful crop (*Figure 7.12*). A poor stand can never produce a high yielding crop and will contribute to other production problems including increased weed and disease pressure. Subsequent management and other inputs cannot compensate for a bad stand. Components of a good stand include rapid and high emergence of uniformly spaced plants of similar size at the target plant population. The sugarbeet planter is a key element of the crop production system. It must perform properly to achieve a good sugarbeet stand. Planting sugarbeet is different from,



**Figure 7.12**

An excellent stand of sugarbeets displaying high field emergence, accurate spacing between plants, and uniform plant size.

and requires more precision than, the planting operation for most other common row crops. Regardless of the specific planter or planting system used, there are a number of critical issues for the sugarbeet planter and planting operation.

## Seedbed

**G**ood seedbed preparation and condition are necessary for planter operation. Good depth control is necessary for sugarbeet seed normally planted  $3/4$  to 1 inch deep. Seed depth control is often more a result of the seedbed than the planter. The seedbed must be relatively level and free of small surface ridges left by tillage. Small ridges, large clods, or rocks will interfere with good seed depth control and ultimately good emergence. Soil moisture also is important. When the soil is very dry, it is difficult to make a distinct seed furrow and firm the soil around the seed. When the soil is too wet, it can be difficult to close the furrow or the depth gauging wheels and press wheels can cause soil crusting over the seed. An irregular soil surface also may cause sufficient planter vibration to interfere with seed metering or with consistent movement of the seed through the seed drop tube.

## Seed Coating

**S**ugarbeet seed is irregular in shape and size, making singulation within any seed metering device difficult and often inaccurate. Seed breakage can be a problem in planters with mechanical metering devices. Partial seed coatings of 5-30 percent material by weight can make a large improvement in metering consistency. This coating makes the seed a more uniform shape, although still not completely round or smooth. Pelleting is the next step and makes the seed surface very smooth, nearly spherical, and very consistent in size. When properly adjusted, almost all planters will have good metering with pelleted seed. Comparisons on a grease belt test stand and in the field have shown that plant spacing is usually better with pelleted seed than with partially coated or raw seed. The more uniform shape, larger size, and additional weight contribute to more

uniform movement through the metering unit, seed drop tube (if the planter has a seed tube), and into the seed furrow. There is also evidence comparing results on a grease belt test stand and field measurements that the pelleted seed has less roll or bounce within the seed furrow (*Figure 7.13*).

To supplement the seed coating, most planter operator manuals recommend using graphite or talc to improve the “flow” of seed in a mechanical metering unit, or the “seating” of the seed on the plate of a pneumatic planter. This is often recommended even with pelleted seed. Consult the operator’s manual for your particular planter for the correct material to add to your seed hopper.

**Figure 7.13**

Sugarbeet seed is sold with different types and quantities of coatings. On the left is bare seed. Pelleted seed is on the right. The middle two samples have intermediate quantities of coating material.



## Field Speed

With few, if any, exceptions, seed spacing within the row and seed singulation within the seed metering unit will improve as field speed decreases. There are several reasons why faster field speed will decrease planting accuracy:

1. **Metering mechanism operates too fast.** At some field speeds, components of the metering unit turn or move too fast for seed to respond to gravity or inertia forces to operate properly. Close spacing between seeds, compared to wider seed spacing, also causes the metering mechanism to turn faster. For example, picture a mechanical plate planter with a horizontal plate. At some high rotational speed of the plate, seed will not have time to drop into all plate cells, creating some skips. With a pneumatic planter, if the seed plate rotates too fast, there is a tendency for seed to be knocked off by brushes or “multiples eliminators”, or the seed may be “thrown” off by centrifugal force. The planter operator must always make a compromise between field capacity (acres planted per hour) and seed spacing accuracy. With almost all planters, a noticeable decrease in seed spacing accuracy occurs at speeds above 3 1/2 mph.
2. **More planter vibration.** The planter tends to move up and down as it passes over soil clods or an irregular soil surface created by tillage. If the right combination of field speed, gauge wheel size, and spacing between soil surface irregularities, etc. occurs, the planter can vibrate to the extent that seed can fall prematurely off the seed plate of a pneumatic planter or bounce within the seed drop tube. This vibration also can affect seed depth.



3. **More roll and bounce in furrow.** As field speed increases, there will be more roll and bounce of the seed as it falls into the seed furrow. While seed is within the planter, it is moving in the same direction and at the same speed as the planter. If the planter is traveling at 5 mph, the seed is moving in the horizontal direction at 5 mph even when it is falling down the seed tube. Unless there is some planter provision to negate this horizontal seed velocity, the seed will hit the furrow with the same horizontal velocity as the planter field speed. To better understand this problem, wad a piece of paper into a round ball. With your arm about 2 feet above a table and the paper ball in your hand, move your arm parallel to and over the table at what you think would be about 5 mph. Simply release the paper ball from your hand without throwing it. What happens? First, there is some bounce in the vertical direction because you dropped it 2 feet. Second, the ball tends to roll or bounce in the horizontal direction along the top of the table because it had the same horizontal velocity as your arm when you released it. This is exactly what happens when a seed is released from the planter. Study the seed on a grease belt test stand. When the seed is released from the planter seed drop tube, it does not roll or bounce on the belt because the seed is “captured” by the sticky oil. Run the belt without the oil and you will see the seed bounce up and down, **and** roll or bounce along the belt surface because of the relative speed difference between the planter and belt surface.

What can be done to minimize this horizontal roll and bounce in the furrow? Decreasing field speed will help. Good furrow shape will help “capture” the seed and prevent movement. Several planter features also can help. One is a seed tube that is curved to the rear at the bottom of the tube. This imparts a rearward velocity or direction to the seed to partially counter the forward speed or direction of the seed. A second and very effective method used on a number of European high speed precision sugarbeet planters incorporates a vertical seed plate that delivers the seed directly to the seed furrow without a seed tube. The plate releases the seed at a position on the plate that literally “throws” the seed rearward into the furrow. The seed plate diameter, rotational speed, and release point have been designed to impart a rearward velocity to the seed that is similar to the forward velocity of the planter. The net result is that these planters can be operated at field speeds of 5 or 6 mph with very little roll or bounce of the seed



**Figure 7.14**

Note the excellent plant spacing in this field. This field was planted with a planter that utilized a metering mechanism that imparts a rearward velocity to the seed to minimize seed roll and bounce in the seed furrow.

**Figure 7.15**

German-made Kleine Unicorn-3 sugarbeet planter which utilizes the feature of imparting a rearward velocity to the seed to counteract the forward velocity created by the forward motion of the planter.



in the furrow. This feature, coupled with a very short seed drop from the seed plate to the furrow, results in accurate seed spacing even at high field speeds (*Figure 7.14*). An example of this type of planter is the Kleine Unicorn-3 shown in *Figure 7.15*.

## Planter Maintenance

A planter that has been well maintained can give many years of good service. A planter that is not well maintained can have poor performance in the first season of use. Carefully review your planter operator's manual for periodic maintenance and preventive maintenance. A review of the diagnostic section of the manual will alert you to potential problems. A thorough review of planter features to inspect for maintenance is beyond the scope of this production guide, but the following are general areas that address frequently occurring problems:

### Static Calibration for Deere MaxEmerge with Pneumatic Metering Unit

1. Raise planter tool bar with three-point or with a jack sufficient to allow the drive wheel to be turned by hand and to allow a container to be placed under the seed tube outlet to catch seed. Put secure blocks under planter frame.
2. Using a flexible tape measure, determine the circumference of the drive tire. (For this example, 91.5 inches, based on a 7.60-15 SL tire size).
3. Remove the cover door of the metering mechanism for one row beside the planter drive tire to observe the seed plate rotation.
4. Place a reference mark or piece of tape on the drive wheel. Turn the wheel at least one turn to remove slack in chains. Turn the drive wheel slowly two turns while someone counts the number of cells in the seed plate that move past a reference point. This represents the number of seeds that **should** be delivered with two turns of the drive wheel. (For this example, 46 cells in two turns of the drive wheel).
5. Divide the approximate distance traveled (two times the drive wheel circumference —  $2 \times 91.5 = 183$  inches for this example) by the number of cells observed in two turns of the drive wheel (46 for this example). The result ( $183/46 = 4.0$  inches) will be the nominal

- Carefully inspect seed plates and cutoff devices on mechanical planters and seed plates and air seals on pneumatic planters.
- With the planter raised, turn the planter or unit drive wheel. Look for any irregular rotation, “jerky” motion, or difficult turning at some point in the rotation. For example, one bad link in a roller drive chain can cause intermittent rotation of the seed plate and resulting problems with seed spacing. Seed plates in a pneumatic planter should turn easily and uniformly.
- Check seed drop tubes. Inside surfaces must be clean and very smooth with no buildup of seed coating material. Wear on the outside of the seed tube at the bottom suggests the tube is not centered between the opening disks and seed will not be delivered to the bottom of the furrow.
- Check wear of opener disks and contact of disks. Disks that are worn or not properly contacting soil will not make a distinct furrow shape and can cause problems with seed spacing and seed depth control.

## How to Calibrate a Planter for Sugarbeet

**A**ccurate calibration of your planter is critical for obtaining the correct seed or plant population, and for minimizing skips and doubles. Complete calibration for your particular seed, field speed, and seed spacing entails four steps:

- 1) set up planter according to the operator’s manual;
- 2) collect seed from planter in static position;
- 3) carefully uncover seeds when you begin planting and measure seed spacing; and
- 4) continually observe output from your planter seed monitor.

spacing between seeds that you can expect if the planter delivers exactly one seed per plate cell. If this is not what you want, change the planter transmission accordingly.

6. Replace the metering unit cover door, put seed in all the hoppers, start the tractor, and set the planter vacuum level. Turn the planter drive wheel several turns to load seed onto the seed plate. Place containers below the seed tubes to catch seed.
7. Turn the drive wheel exactly two turns. Count the seed collected below each row unit. (All rows count between 45 and 47 for this example.) If the seed count differs more than two or three from the number of plate cells counted in Step 4, adjust the vacuum or check the match between seed size and plate hole size. If this doesn’t improve seed delivery, check for vacuum leaks or other maintenance items.
8. When you first begin planting and occasionally thereafter, stop, and carefully uncover 5-10 consecutive seeds in several rows. Measure spacing between seeds and look for skips and doubles.
9. Once you are satisfied with seed spacing and seed singulation, check your planter seed monitor often. Any change or differences among row units indicated by your monitor is a signal that something requires attention.



*Accurate planter calibration is critical for obtaining the correct seed populations and minimizing skips or double seeding.*

### **Set According to the Operator's Manual**

Carefully follow the operator's manual for planter components (such as particular seed plate, etc.), vacuum level (for pneumatic planters), planter transmission setting, and any other adjustments for the particular seed spacing and seed size chosen. Drive tire size and inflation pressure must be the same as specified in the operator's manual. This should be a good first setting but may not give the exact seed spacing or seed metering that you need.

### **Perform a Static Calibration Test**

To do a static calibration test, raise the planter drive wheel with the tractor three-point (if three-point mounted) or with a jack. Carefully block the planter frame with secure blocks or jack stands. Never get under the planter without properly blocking the planter! Before putting seed into the hopper, turn the drive wheel by hand two turns and count the number of cells in the seed plate that pass some reference point. This number is the number of seeds that should be planted in two turns of the drive wheel. Measure the circumference of the drive tire by bending a tape measure around the tire. Multiply this distance by the number of turns of the drive wheel (two, in this example). Divide the distance covered by two turns of the drive wheel (in inches) by the number of cells of the seed plate for two turns of the drive wheel. The result will be the distance (in inches) between seeds if everything works correctly for the planter.

Put seed in the hoppers and set the vacuum level if pneumatic. Turn the drive wheel by hand several turns at a uniform speed that approximates your field speed to fill the cells in the seed plate. Put a mark on the drive wheel to reference a starting and ending point of the rotation. Sweep the floor or soil surface of any seeds already dropped. Place pans under each row unit to catch the seed. Turn the drive wheel two complete turns, accurately starting and stopping at the marked point, at a rotational speed similar to field speed. Count the number of seeds collected from each row and compare to the number of seed plate cells advanced by two turns of the drive wheel. If these numbers are different by more than three seeds, further diagnosis must be made. Was the number of seeds from each row the same? If not, there is something different about the individual rows which also requires further diagnosis.

## **Planter Test Stand**

**P**lanter test stands are important tools to verify that planter units are in top condition prior to planting, and to examine the effect of new components on metering performance. For example, it is easy to determine the effect of vacuum level on seed metering in a pneumatic planter, or whether a particular seed sample will match a certain plate for a mechanical planter. It is recommended that all planter units be tested on a planter test stand each year.

One word of caution with a planter test stand: It is a good method of evaluating the performance of the metering unit and seed tube; however, the ordinary grease belt test stand will not account for the roll or bounce of the seed that can occur in the actual seed furrow in the field. The oil on the grease belt "captures" the seed and prevents roll and bounce; making seed spacing appear much better on the grease belt than it will in the field.



## General Purpose “Corn” Planter or Precision Sugarbeet Planter?

**S**ugarbeet seed is smaller than corn seed, more difficult to meter one seed at a time, is planted more shallow than corn seed, and is more difficult to germinate and emerge. The best corn planters have been designed for corn and similar seeded crops. They have metering units 18-24 inches above the soil surface to provide clearance for residue movement and for soil engaging accessories. Furrow openers have been designed to create a furrow 2 or 3 inches deep for a large seed and press wheels to close this large furrow. Metering units and seed drop tubes work well with large seeds. Even the seed sensors are designed for relatively large seed. Although these planter features are very effective for corn, such planters must be modified for sugarbeet planting and will require compromises to enable one planter to plant all row crops.

Since sugarbeet seed is so much different than corn seed, it is only logical that a good sugarbeet planter would be designed specifically for sugarbeet planting. Prior to about 1980 most sugarbeet producers had one planter specifically for sugarbeet and another planter for crops such as corn and edible bean. Current practice in the United States is that most sugarbeet fields are planted with planters designed primarily for corn and similar crops, but adapted for sugarbeet. In contrast, in Europe, almost all sugarbeet fields are planted with precision sugarbeet planters, and other planters are used for larger seeded crops like corn, bean, or sunflower. Planters designed for sugarbeet ordinarily have very short seed drops, press wheels specifically for pressing soil around the shallow planted seed, and may have features described earlier that impart a rearward velocity to the seed to minimize seed roll and bounce in the furrow at high field speeds. As seed cost increases, as the sugarbeet acreage for each grower increases, and as the reasons for accurate plant spacing become more important, it is likely that more growers will use specialized planters for sugarbeet. These specialized planters will need to be designed with features desired by growers including good strength, high speed operation, accurate seed spacing, residue handling ability, and ease of adjustment for seed type, seed spacing, and seed depth (*Figure 7.16*).



**Figure 7.16**  
Monosem Meca 2000 planter designed specifically for sugarbeet. This planter is popular in France and incorporates a unique mechanical metering system for pelleted seed to minimize seed roll and bounce in the seed furrow.

## Planter Adaptability

**I**t is important that a planter can be easily and quickly adjusted for a variety of planting conditions. It would be advantageous for the planter to be able to plant pelleted and unpelleted seed and with a minimum of changes. Soil conditions can change within a field or between fields, requiring changes in seed depth. Soil moisture, expected weather conditions, and potential germination of the seed will require seed spacing changes. The planter should allow these two changes to be made easily and rapidly. If not, the changes probably will not be made and stand may be less than it could be. Down-force on the press wheels should be easily adjustable to match soil conditions.

## Seed Monitor

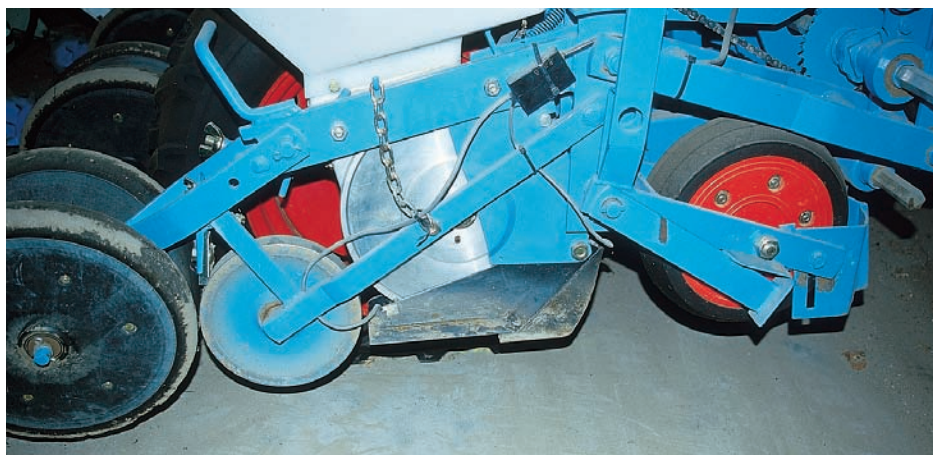
**O**nce considered a luxury option, seed monitors are now a necessity to avoid empty seed hoppers and to monitor seed population. Keep the monitor system in accurate operating condition and use it to detect any changes in metering performance. If one row or all rows of the monitor display erratic seed spacing or seed population, do not assume that there is a problem with the monitor and disregard the monitor. Many operators have assumed the monitor was inaccurate, and later learned that in fact the planter was not performing properly.

## Seed Firming Wheels or Devices

**N**on-rotating devices that slide over the seed in front of the press wheels are usually discouraged for sugarbeet because the seed can be moved in the furrow, decreasing seed spacing accuracy. Narrow wheels with soil scrapers or flexible rubber tires running in the furrow to push the seed into the bottom of the furrow are thought to provide some improvement in germination. There is little research to document this improvement under U.S. conditions. A key factor may be that for these seed pressing wheels to be an advantage, the soil below the furrow must be firm and moist to assist in increased movement of moisture from the soil below the seed to the seed. European sugarbeet planters almost always include a seed press wheel to push the seed firmly into the bottom of the seed furrow. If the soil type or condition is very “sticky,” observe that these seed firming wheels do not pick up or move the seed.

## Row Firming or Cleaning Accessories

**F**irming or row cleaning devices ahead of the planter row unit can be beneficial in certain situations. Removal of large soil clods or excess crop residue from the row area is beneficial. A firm, smooth surface will enhance seed depth control and seed germination. There are two cautions with these types of accessories: 1) Do not expose fresh, moist soil that is immediately passed over by the planter gauge wheels and press wheels. This is likely to cause soil crusting. 2) Do not create a depression for the planted row. Precipitation or sprinkler irrigation can collect in this depression, causing a dense, smooth layer of soil over the row, again leading to soil crusting. Consider spoke wheel-type row cleaning devices instead of solid or notched disc row cleaners. Spoke wheel row cleaners will remove most large clods and residue from the row area without moving as much soil as a solid disc row cleaner.



**Figure 7.17**

Note stainless steel seed firming wheel behind the runner opener on this Monosem Meca 2000 sugarbeet planter.



**Figure 7.18**

Planter metering mechanism “flat plate” design with simple holes on the left, and “cell plate” design on the right with cell shape to partially contain the seed. The cell shape must match the seed size and shape to obtain good seed singulation with the design type on the right.

## Pneumatic vs Mechanical Seed Metering

Most U.S. manufactured planters used for sugarbeet use pneumatic (positive air pressure or vacuum) seed metering. These pneumatic units generally have two advantages over most mechanical metering devices for unpelleted seed — elimination of seed breakage and wider range of seed size or shape without changing seed plates. Most U.S. manufactured pneumatic planters use a seed plate with a depressed cell to fit a particular size seed. Seed singulation is adjusted by changing the seed plate and/or changing the flow of air through the plate holes. This design requires many different plates to cover the range of unpelleted and pelleted seed sizes. The plate cell must fit the size and shape of the seed to minimize skips or multiples (*Figure 7.18*). Newer, European influenced designs use a “flat plate” system. Seed plates for these systems have holes in the plates but no cells to confine the seed. Usually the plate holes can be sized so one plate can be used for almost the entire range of commonly used pelleted and unpelleted seed sizes. Seed singulation is adjusted by changing the air flow and by altering the “seed bumping” mechanism (*Figures 7.19 and 7.20*). The plate hole is sized and the air flow is sufficient so that all plate holes attract at least one seed. The “seed bumper” actually “bumps” the seed or seeds that are held by the air flow on each hole of the plate. The bumping device usually bumps each seed more than one time. The more advanced designs, such as the Case IH ASM planter, bumps the seed from the side toward the plate center and



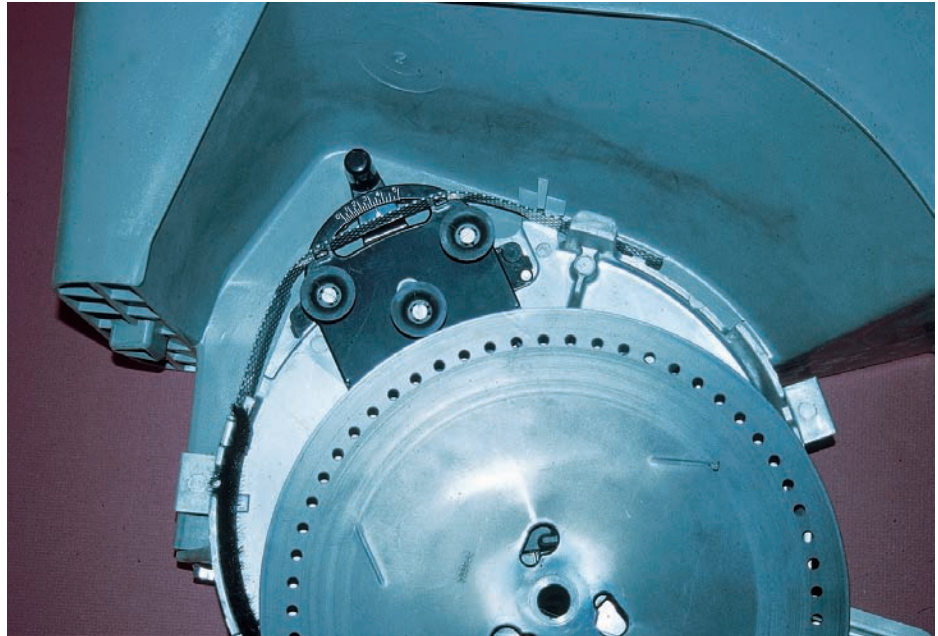
then from the opposite side of the seed. This bumping action is very effective in insuring that only one seed is held by the air flow on the plate hole. These systems are very effective for seed singulation, even for unpelleted sugarbeet seed.

## Furrow Opener

**M**ost planters currently used in the United States for sugarbeet have a double disc furrow opener. A small proportion of these planters have an auxiliary runner or shoe opener designed to improve the shape of the furrow bottom. In contrast, almost all European sugarbeet planters use a shoe or runner type

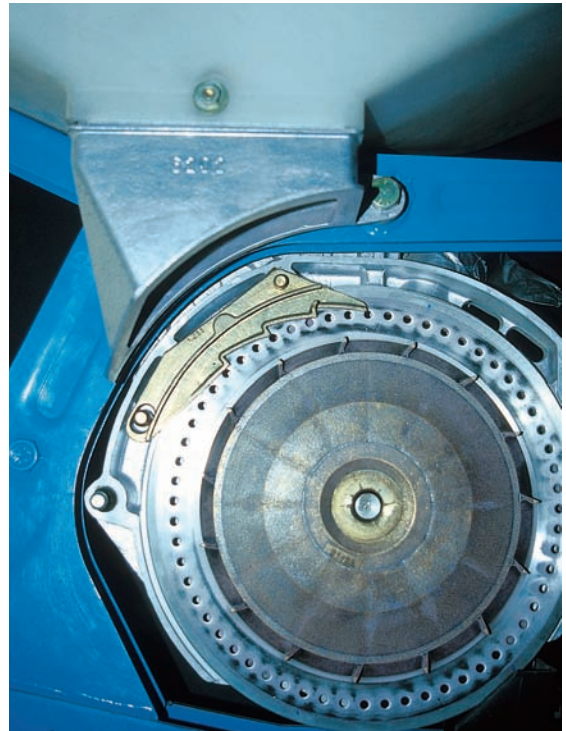
**Figure 7.19**

Case-IH ASM planter metering mechanism showing “flat plate” pneumatic metering design with three seed “bumpers” to eliminate multiples on the cell plate holes.



**Figure 7.20**

Monosem NG Plus metering mechanism with “flat plate” design and stepped seed “bumper” to eliminate multiple seeds on the “flat plate.”





furrow opener (see *Figure 7.17*) and a few have auxiliary double disc openers. There are specific advantages for each furrow opener type.

Double disk openers cut through, or more often, run over any crop residue without plugging or without dragging residue to make a wide seed furrow. Compared to a runner-type opener, double disc openers rarely plug if the planter is lowered to the soil without forward movement of the planter. If the discs are properly maintained, this type of opener makes a sharp “V” shaped furrow bottom. If the discs are worn or do not match properly, there is not a distinct “V” shape to the bottom of the furrow but rather a “W” shape. This will create problems for seed depth control and seed alignment in the furrow.

Runner or shoe type openers are favored in Europe for at least two reasons. First, European sugarbeet planters are designed with the metering mechanism very close to the soil surface. A shoe opener can be placed below the metering unit without causing a long seed drop. It is difficult to position a seed metering device between a double disc opener and achieve a short seed drop. Second, the Europeans believe that if the seedbed is firm, a shoe type opener will make a firm bottom in the seed furrow. If the seed is pushed into this firm furrow bottom by a seed firming wheel that is following immediately behind the opener but before soil falls into the furrow, very effective seed-to-soil contact is made. This seed-soil contact will effectively transfer soil moisture from below and around the seed to the seed and improve emergence. If the seedbed is loose and cloddy (“unconsolidated”) below the seed, a firm furrow bottom is not possible, and effective seed-soil contact is not likely until irrigation or rainfall “melts” the clods and firms the soil around the seed. If there is residue on the soil surface, the European planters use a double disc opener before the runner to deflect residue or push the residue into the soil so the runner will pass over it without plugging.

## Press Wheels

**T**he sugarbeet planter press wheels have three primary purposes:

- 1) to facilitate soil movement into the seed furrow to cover the seed with the desired depth of soil;
- 2) to firm the soil at seed depth to create good seed-to-soil contact and firm the soil over the seed to minimize soil moisture loss; and
- 3) to create a soil condition over the seed that will minimize soil crusting if precipitation or sprinkler irrigation occurs.

There are many theories regarding ideal use of the press wheel, several of which are logical and verified by practice:

- It is better to close the seed furrow by applying pressure to the soil from beside the furrow, rather than scraping soil into the furrow from the soil surface. Soil from the surface will likely be dry and cloddy. If the sides of the furrow can be “squeezed” together with a minimum of soil coming from the surface, there will be less dry, cloddy soil directly over the seed. Concave furrow closing discs that precede the press wheel or dual angled press wheels are effective for this purpose.
- The seed must be covered with the correct and consistent depth of soil, and the seed-to-soil contact must be firm and consistent or emergence will not be consistent.

*Irregularities in the soil surface above the seed will help minimize crusting and facilitate emergence.*

- The soil surface above the seed (but not the soil immediately around the seed) should have irregular surface contour, irregular soil firming, and small soil clods. These “irregularities” in the surface soil above the seed will minimize soil crusting. Following a medium or light rainfall or sprinkler irrigation, the soil will dry unevenly in areas that have clods, an irregular surface contour, or different levels of soil firming. As the soil dries unevenly, the soil expands or contracts unevenly and creates stresses within the soil. These soil stresses lead to weaknesses or cracks within the soil as it dries and create a soil crack. Emerging plants can take advantage of the soil cracks or weak areas and push through the crust. Dual angled press wheels, single rib press wheels that leave a distinct mark in the soil surface over the seed, herringbone press wheels, shallow tine scratchers, and drag chains all help to create “surface irregularities” that can minimize soil crusting after a light or moderate rain. Avoid press wheels that leave the surface flat and smooth with no surface clods. A sudden, hard rain will likely cause the soil to crust regardless of the type of press wheel design.

## Tips for Popular Planters

Only a limited number of planter models are used for sugarbeet in the Nebraska, Colorado, and Wyoming growing area. These include the John Deere MaxEmerge with pneumatic metering option, John Deere 71 Flexi-planter, Monosem NG Plus, Milton, White Seedboss, and WIC. It is estimated that 70 percent of the acreage is planted with the MaxEmerge, 15 percent with the 71 Flexi-planter, and the remaining acreage distributed among the other planters. Annually review the operator’s manual for your planter. These manuals provide the best recommendations for maximum operating performance. Also review the diagnostic section of the manual for tips about problems to avoid. Because of the popularity of the MaxEmerge and 71 Flexi-planter in this growing area, several operating recommendations are provided.

### John Deere 71 Flexi-planter

- If you need to space seeds more than 4 1/8 inches apart, consider two alternatives instead of the “extended drilling distance” option that requires an additional shaft, two sprockets, and two short chains in the chain case.

**Figure 7.21**  
Some of the press wheel options for the John Deere 71 Flexi-planter.





**Figure 7.22**

Note assortment of press wheel options on the German-made Klein Unicorn-3 sugarbeet planter. The goal is to create “discontinuity” of the soil over the seed.

One alternative is to use a 7-tooth drive sprocket instead of the smallest 9-tooth sprocket listed in the operator’s manual. The 7-tooth sprocket is custom made and is available in areas where the John Deere 71 planter is commonly used. The 7-tooth driver and 22-tooth drive sprocket combination will provide a seed spacing of about 5 1/4 inches. A combination of 7-tooth and 20-tooth sprockets will space seeds approximately 4 3/4 inches. The second alternative is to use plastic 36-cell plates instead of the standard 72-cell plates. The 36-cell plates are manufactured and sold by Lincoln Ag-Products Co., Box 5346, Lincoln, NE 68505, phone: 402-464-6367. These plates have indents in the positions where the other 36 holes are in an ordinary 72-hole plate. To operate properly these 36-cell plates must have indents in the top side of the plate, when positioned in the planter, to enable the star knocker wheel to turn properly. Without these indents, the star wheel does not turn regularly in some planters and plate cell holes may plug with seed, causing skips. To determine seed spacing with the 36-cell plate, simply double the spacing for the 72-cell plate listed in the operator’s manual.

- Inspect and replace the seed cutoff often. Also check star wheel knockout assemblies and seed plates for wear.
- Seed tubes with seed sensors are available for the 71-Flexi-Planter for sugarbeet. This helps assure all units are functioning properly and the seed population is correct.
- Check opener discs for wear and for maximum contact. This is essential for forming a sharp “V” furrow shape to provide desired seed depth and alignment of the seed down the row.
- Consider press wheel options (*Figure 7.21*) and increasing or decreasing spring down pressure on the press wheels or on the entire unit. The chevron or herringbone style press wheel is most commonly used for sugarbeet, but some growers prefer the single rib press wheel. The press wheel that leaves a narrow (3/4-inch wide) ridge over the seed furrow also provided good emergence in trials comparing all available press wheels. A trailing drag chain will provide some clods and roughness over the furrow to assist in wind erosion protection and minimize soil crusting problems.



*The corn, sugarbeet and straight seed tubes each offer advantages. No single type is right for all planting conditions.*

## **Deere MaxEmerge Planter (pneumatic meter option)**

### **Press Wheels**

Planters manufactured after about 1992 have adjustable press wheel spacing. Standard spacing for corn and dry edible bean is 1 inch at the closest point at the bottom of the wheels. This wide spacing is best for crops planted 2 inches deep but can cause problems for shallow seeded crops. When the soil is moist and firm, it may be difficult to attain complete and consistent furrow closing with the wide press wheel spacing. If the soil is dry and loose, the wide spacing causes soil, and sometimes the seed, to push up between the press wheels, which results in uneven seed depth. For sugarbeet the press wheel spacing should be approximately 1/2 inch. This will allow more spring down force on the press wheels to get furrow closing in all conditions without having soil push upward between the press wheels.

### **Seed Tubes — Which One Should be Used for Sugarbeet?**

At least three seed tube designs are available for the John Deere MaxEmerge planter series. These tubes are generally termed the corn tube, the straight tube, and the sugarbeet tube. Inserts are available for the corn and straight tubes. All combinations of seed tubes and inserts have been used for sugarbeet with varying degrees of success. Generally, the inserts improve delivery of the seed into the bottom and center of the seed furrow behind the furrow openers. An original purpose of the seed tube inserts was also to channel the seed at the top of the tube to get better response from the seed sensors. A disadvantage of the seed tube insert is that it creates more contact with the seed than the seed tube without insert. This increased contact results in drag or bounce within the insert and decreased consistency of spacing between seeds in the furrow. Current information and field research data suggests that the inserts should not be used for sugarbeet for most applications.

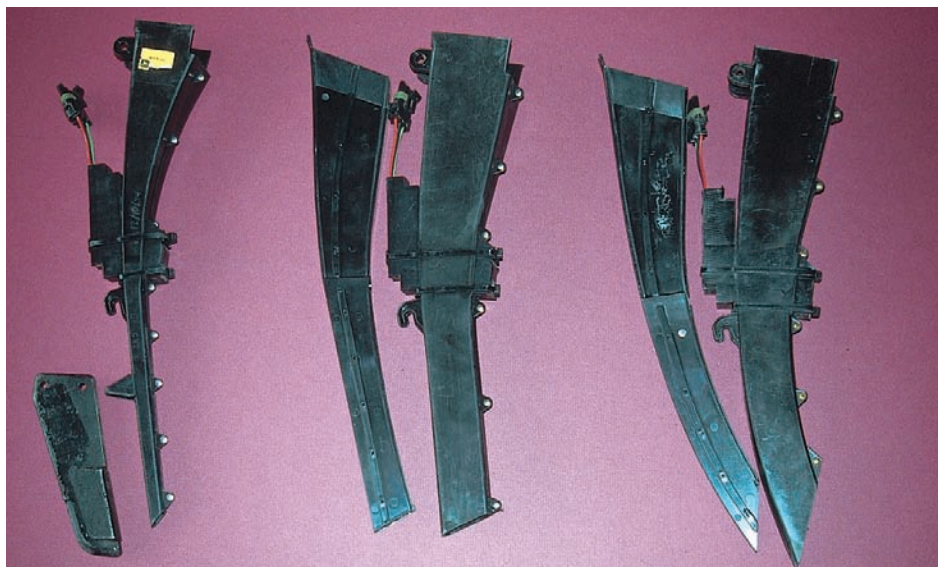
There are advantages and disadvantages for each of the corn, straight, and sugarbeet tubes, and one tube is probably not best for all sugarbeet planting applications.

**Corn Seed Tube** — The corn seed tube is recommended by Deere as the tube which will provide the most consistent and accurate seed spacing within the row. Recent field research at the University of Nebraska confirms that the corn tube will provide as good or slightly better seed spacing accuracy within

**Figure 7.23**

John Deere MaxEmerge planter with pneumatic seed metering option. This is a very popular general purpose planter in the United States.





**Figure 7.24**

Seed tube options for the John Deere MaxEmerge planter for sugarbeets. On the left is the seed tube and associated runner specifically designed for sugarbeets. The “straight” seed tube in the center is popular for sugarbeets in many areas. The “corn” seed tube is on the right. Inserts are shown with both the “straight” and “corn” tubes.

the row compared to the straight tube or sugarbeet tube. One possible reason for better seed spacing with this seed tube is the curve at the bottom of the tube. This curve imparts a rearward direction and speed to the seed to counteract part of the forward speed of the planter to help minimize seed roll and bounce in the furrow.

One disadvantage with the corn tube is that the seed is delivered to the seed furrow a substantial distance from where the furrow was opened and some soil may begin to fall back into the furrow before the seed reaches the bottom of the furrow. This can cause depth control problems if the soil is dry and loose, and with lower field speeds. In addition, not all seeds exit the bottom of the tube from the front inside surface of the tube. Occasional seeds bounce within the tube and exit higher from the tube opening. These seeds have a greater chance of not reaching the bottom of the seed furrow and may not have the desired seed depth or alignment within the row. Some growers address this depth control concern by replacing the seed tube rock guard with a runner such as that made by ACRA-PLANT. This runner will hold the furrow open long enough for seed to reach the bottom of the furrow.

**Sugarbeet Seed Tube** — The narrow sugarbeet tube was designed by John Deere to direct a small seed, such as sugarbeet seed, to the bottom of the seed furrow for good depth control. The runner opener which accompanies this seed tube creates a firm, distinct furrow bottom, and holds the seed tube in line with the furrow. Disadvantages of this tube are that the seed spacing may not be quite as good as the corn tube or straight tube, and that this tube cannot be used with corn or dry edible beans. The sugarbeet tube will provide good depth control but seed spacing within the row will not be quite as good as with the corn or straight tubes.

*Improper seed tube placement can affect depth control, seed spacing and plant alignment in the row.*

**Straight Seed Tube** — The straight seed tube (it actually has a slight bend near the middle of its length) is perhaps a compromise between the corn tube and sugarbeet tube. This tube is recommended by researchers and crop advisors in the North Dakota-Minnesota growing area. Recent field research at the University of Nebraska indicates that the straight tube will have seed spacing accuracy within the row similar to the corn tube and slightly better than the sugarbeet tube. However, the straight seed tube will have better seed depth control than the corn tube, but not as good as the sugarbeet tube.

In addition to selecting the best seed tube option for your particular planting conditions, maintenance of the tube is also very important. Check the bottom of all seed tubes to be certain they are centered with the seed furrow. If the seed is not directed to the center of the seed furrow, the seed must roll or bounce from the side of the furrow to the bottom. This can cause problems with depth control, seed spacing, and alignment of the plant within the row. Any wear on the side of the seed tube at the bottom indicates a serious misalignment. The inside of the tube must be clean and very smooth. Check the sensor position in the tube that it does not create a sharp edge to cause the seed to deflect.

#### **Chain Drives**

Check all chain drives for smooth, regular operation. If the drive does not operate smoothly, seed spacing will be inconsistent. Look for stiff links, sprocket misalignment, or irregular turning of the granular chemical application metering units.

#### **Wear of Metering Unit Components**

Carefully inspect all components within the metering unit for wear before the planting season and after a significant number of acres have been planted. Examine the vacuum seals for wear or cracks, especially at the seal corners. Look at the brush and seed plate for noticeable wear, and if found, replace them. Make sure the seed plate turns with minimal drag, for the full rotation of the plate, with no warp or wobble.

#### **Consistent Vacuum in All Units**

Most planters monitor vacuum level in only one row. After extended use, the vacuum level can vary among rows because of seal wear, etc. If the planter is planting regular sugarbeet pellets at 3-5 inches of water vacuum, the vacuum level can be off by as much as 1 inch of water without a major problem. However, if the medium plate is used with medium seed, the vacuum level required may be as low as 1/2 or 3/4 inch of water. In this case, a variation of 1/2 inch of water vacuum will create a large inconsistency in seed metering from row to row.

Consider adding a vacuum hose fitting to the meter cover/lid of all rows instead of just one row. With a longer hose, if necessary, occasionally check the vacuum in all rows by temporarily connecting each row to the vacuum gauge. Place a cover on the vacuum fitting of all rows not connected to the gauge.



**Table 7.4**Suggested seed plates and vacuum levels for John Deere MaxEmerge planter<sup>1</sup>.

Seed Size		Seed Plate	Vacuum Level (inches of water)	Comments
Description	Approx. Diameter x thickness (inches)			
Small	7-8/64 x 4-5.5/64	A51712	1 to 1 1/2	
Medium	8-9/64 x 4.5-6.5/64	H136445	3/4 to 2	
Large	9-10/64 x 4-6.5/64	A51713	1 to 1 1/2 (Caution!)	There is not a good plate for this seed size.
Extra Large	9.5-11/64 x 5-7/64	A51713	1 to 1 1/2	
Mini-Pellet (M2)	8-10/64 dia	H136445	1 1/2 to 2	
Regular Pellet (M4)	9.5-11.5/64 dia	A51713	3 to 5	
Jumbo Pellet (M5)	11.5-13.5/64 dia	A43066	5 to 8	

<sup>1</sup>These seed plate and vacuum level combinations are suggestions for initial settings. Final settings will depend on the particular planter, seed, and planter operation. Final settings must be fine-tuned with careful examination of seed drop within the furrow, careful observation of seed population with a seed monitor, or other calibration techniques.

## How to Measure Actual Plant Population and Percent Field Emergence

**I**t is important to know the actual plant population and percent field emergence in sugarbeet fields to decide about replanting or thinning, and to plan for next year's planting. These measurements are relatively easy, do not take long, and can be done when examining the crop for other management decisions. Several years of history of both plant population and percent emergence in your own fields will provide an excellent basis for selecting the best seed spacing.

### Plant Population Measurement

An established stand of sugarbeet is usually measured at about the six true-leaf stage. By this time seedling diseases, frost, and wind damage will normally not reduce the population any further. Insects and diseases can, of course, reduce the plant population as the season progresses. There are many methods of measuring plant population, but the following procedure is reasonably accurate and easy. Locate at least five spots (ten spots would provide an even more accurate measurement) within the field. These locations must be random and not selected because they appear "good", "normal", or "bad". Throw some object into the field to locate the random spot and begin measuring at this spot. Divide the field into four quarters. Locate measurements within each section and one more measurement near the center of the field. Count the number of plants in 50 feet of each of two adjacent rows for a total of 100 feet of row at each location. Average the plant counts from the locations to obtain an average value for

**Knowing actual plant population and percent field emergence aids management decisions and planning.**

plants per 100 feet of row. Multiply the average number of plants per 100 feet of row times 238 for 22-inch rows or times 174 for 30-inch rows to obtain the average number of plants per acre for the field.

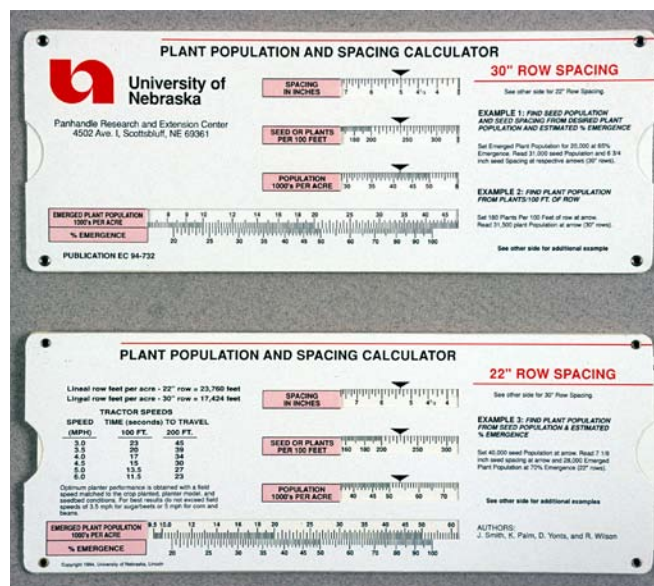
### Percent Field Emergence Measurement

Percent field emergence can be estimated by dividing the average plant population (determined above) by the average planted seed population. Average seed population can be determined several ways. One method is to use the seed spacing setting of the planter. Convert seed spacing (inches per seed) to seeds planted per acre. This method assumes (often incorrectly) that the planter seed spacing is accurate and that one seed is dropped for each cell of the planter plate. A much more accurate method is to mark the distance traveled in the field by five turns of the drive wheel of the planter (or the drive wheel of a planter unit for certain types of planters). Then, with the planter stationary and lifted, turn the planter drive wheel five turns by hand at a rotational speed similar to that used in the field and collect the seeds from those five turns. Repeat this process for at least five rows of the planter. Divide the average number of seeds collected per row by the number of inches traveled in the field by five turns of the drive wheel. The result will be the average distance (in inches) between seeds planted in the field. Convert inches between seeds to seeds planted per acre, accounting for the correct row spacing.

Percent field emergence can then be accurately estimated by dividing the established plant population (plants per acre) by the number of seeds planted per acre, and multiplying by 100.

The calculations of plant population, seeds planted per acre, and field emergence can be simplified by using the *Plant Population and Spacing Calculator*, University of Nebraska publication EC 94-732, available from the University of Nebraska or from your sugar company agriculturist (*Figure 7.25*). This slide rule calculator also demonstrates the relationship and sensitivity of seed spacing, row width, and percent field emergence to final plant population. Information from this slide rule is also represented in *Tables 7.2* and *7.3*.

**Figure 7.25**  
“Plant Population and Spacing Calculator” available from the University of Nebraska or your sugarbeet agriculturist.



By *Jürg M. Blumenthal*

**M**anagement practices which provide an adequate, but not excessive, supply of plant nutrients are essential for top yields of high quality sugarbeet in the High Plains. Yields of 22-28 tons per acre at 16-18 percent sugar can be attained most years with good management.

## Soil Testing

**S**oil testing is the foundation of sugarbeet nutrient management. The goal of soil testing is to characterize the amount of nutrients in the soil prior to planting. Fertilizers can then be applied based on the soil test results to ensure optimal nutritional conditions for the crop.

Soil samples from the surface to a depth of 6 feet are necessary for the most accurate prediction of nutrient needs. These samples should be collected to obtain a plow-layer sample (0-8 inches), a sample from 8-24 inches and a sample from each 2-foot increment below 24 inches. Collect composite cores from at least 15 points in the field for the surface sample and from 8-10 points for the deeper samples. More than one set of samples may be necessary from some fields if parts of the field differ in slope or soil characteristics such as color, sandiness or previous crop. For further suggestions on taking soil samples, refer to guidelines published by Cooperative Extension and instructions provided by soil testing laboratories.

The plow layer sample should be analyzed for nitrate and other nutrients, organic matter concentration, and soil pH. The deeper samples should be analyzed for nitrate only. The reasons for this difference are:

- 1) while most nutrients are not very soluble and are mainly in the top 8 inches of soil, nitrate is very soluble, and rainfall or irrigation may leach it from the plow layer; and
- 2) research and experience has shown that sugarbeet can use nitrate-nitrogen from depths of 6 feet or more. Soil samples from the plow layer alone do not accurately predict the amount of nitrogen available to the sugarbeet crop.

## Nitrogen Recommendations

**U**nder most circumstances nitrogen is the most limiting nutrient in sugarbeet production. Nitrogen is a building block of amino acids and proteins in plants. Chlorophyll is the most abundant protein in plants. It is involved in photosynthesis — the conversion of carbon dioxide gas with the help of light energy. Chlorophyll gives plants their green color. Plants deficient in nitrogen contain less chlorophyll and appear light green. With increasing severity of ni-

*Nitrogen, followed by phosphorus and potassium, are the most yield-affecting nutrients for sugarbeet.*



trogen deficiency, leaves will appear yellow and older leaves will age prematurely (*Figure 8.1*). Symptoms of nitrogen deficiency appear first on older leaves.

Proper nitrogen nutrition in sugarbeet production is crucial. Lack of nitrogen will result in significant reductions in root yields, while excess nitrogen will promote significant decreases in sucrose content of the root and excessive leaf growth (*Figure 8.2*). Because of the significant effects of nitrogen on crop yield and crop quality, the goal of nitrogen management in sugarbeet is to supply enough nitrogen during the beginning and middle part of the growing season to ensure optimal crop growth and canopy development and to exhaust soil nitrogen reserves toward the end of the growing season to obtain optimal crop quality.

About nine pounds of nitrogen are necessary for one ton of harvestable sugarbeet. This nitrogen can be obtained from residual soil nitrogen within the rooting zone, become available from organic matter during the growing season (mineralization), or may be applied as fertilizer. Applied fertilizer should be considered a supplement to available soil nutrients. When assessing nitrogen needs of the crop, consider expected yield, organic matter concentration of the soil, and residual soil nitrate-nitrogen.

**Figure 8.1**

Comparison of healthy (right) and nitrogen deficient sugarbeet leaves (left).



**Figure 8.2**

Comparison of excess nitrogen (foreground) and nitrogen deficient sugarbeet (background).



Fertilizer nitrogen recommendations can be calculated using the following equation or by using information in *Table 8.1*.

$$\text{Nitrogen need (lb N/A)} = (9 \times \text{EY}) - (30 \times \text{OM}) - \text{RSN} - \text{other credits}$$

where EY = expected yield (tons/A),

OM = organic matter percent, and

RSN = residual soil nitrogen measured to a 6-foot depth (lb N/A).

Other credits = see *Table 8.2*.

Consider this example: A grower has a field with soil test values of 95 lb residual nitrate-nitrogen in a 6-foot soil profile and 1.2% soil organic matter. For this field, his yield goal is 24 tons of sugarbeets per acre.

The nitrogen fertilizer requirement is calculated as follows:

$$\begin{aligned} \text{Nitrogen need (lb N/acre)} &= (9 \times 24) - (30 \times 1.2) - 95 \\ \text{Nitrogen need} &= 85 \text{ lb N/acre} \end{aligned}$$

The expected yield should be a reasonable estimate of what a grower can produce on a given field. Normally it should not exceed the average of the last five crops by more than five percent.

**Table 8.1**

Nitrogen fertilizer recommendations for a yield goal of 25 tons/A.

Soil test Nitrate-N	Soil organic matter (%)			
	0-1.4	1.5-1.7	1.8-2.1	2.2+
lb/A 6ft	Pounds of N per acre to apply			
0-25	175	165	155	145
26-45	155	145	135	125
46-65	135	125	115	105
66-86	115	105	95	85
86-105	95	85	75	65
106-125	75	65	55	45
126-145	55	45	35	25
146-165	35	25	15	0
More than 166	0	0	0	0

All nitrogen fertilizer sources — ammonium nitrate (33-0-0); urea (45-0-0); urea-ammonium nitrate (28-0-0); and anhydrous ammonia (82-0-0) — are generally very effective; however, dry and liquid nitrogen sources vary in their susceptibility to volatilization or gaseous loss as ammonia into the atmosphere.

*Too little nitrogen will reduce root yields, while too much will reduce sucrose content and increase leaf growth.*

Ammonium nitrate is the least susceptible, while urea is usually the most susceptible. With incorporation soon after application all nitrogen sources should be equally effective.

Recent research has shown that the practice of applying dry nitrogen fertilizer in spring prior to planting had a profound effect on stand establishment. Spring application of 100 lb nitrogen per acre in the form of dry fertilizer reduced stands on average by more than 6000 plants per acre, regardless of fertilizer source and method of incorporation. Under gravity irrigation, it is advisable to apply nitrogen fertilizers in the fall or between the two to six true leaf growth stages. Nitrogen application with sprinkler irrigation is a very efficient method. The practice of weed-and-feed (applying granular fertilizers impregnated with herbicide before planting for the dual purpose of fertilization and weed control) is discouraged because the high amount of fertilizer required to ensure good ground coverage of herbicide for weed control can have a negative effect on sugarbeet stand.

Manure application is not recommended for sugarbeet production and should be reserved for other crops. Much of the nitrogen from manure is released in the latter part of the season and tends to retard sugar accumulation in the root. When alfalfa precedes the sugarbeet crop, or if manure is applied, it must be noted on the soil sample information sheet so that adjustments to nitrogen application rates can be made. The following table can be used as a guide for an average situation (*Table 8.2*).

**Table 8.2**

Guide for adjusting nitrogen recommendations

Previous crop or treatment	Lb N/A to subtract from recommendations
Alfalfa	50
Manure, with bedding, per ton	5
Manure, feedlot run, per ton	7

If manure is applied to sugarbeet, it may need to be tested for nutrients. In such a case, nutrient recommendations must be adjusted by the actual amount of nutrients added with the manure.

## Phosphorus Recommendations

Under most circumstances phosphorus is the second most limiting nutrient in sugarbeet production. Phosphorus is involved in energy transfer within the plant and aids in maintaining the structural integrity of the plant cell membranes. Leaves of plants deficient in phosphorus will appear darker green than usual. With increasing severity of the deficiency, plant growth will be stunted (*Figure 8.3*).



Phosphorus deficiencies will most likely be associated with soils that are high in pH and low in organic matter (eroded knolls under sprinkler irrigation systems and areas of intensive land leveling under gravity irrigation systems). Phosphorus content of many soils in sugarbeet producing areas has increased over

time because the nutrient has been added for several years and now soil test levels tend to be high. This means that phosphate fertilization is not necessary in many instances. On the other hand, adequate phosphorus fertilization is essential for optimum yields on low phosphorus soils. Soils which still need phosphorus fertilization can be identified and properly fertilized by following the recommendation in *Table 8.3*.



**Figure 8.3**

Area of a sugarbeet field deficient in phosphorus

**Table 8.3**

Phosphorus fertilizer recommendations

Phosphorus soil test level (Bray-1 soil test, ppm)	Phosphate application rate (lb $P_2O_5$ /A)
0-5	100
6-15	80
15-25	0
25+	0

Because phosphate is rather insoluble and is not readily transported with water, phosphorus fertilizers must be incorporated into the soil. Phosphate fertilizers are not toxic to sugarbeet and can be safely applied before planting or placed in a band at planting.

## Potassium Recommendations

Most soils in the High Plains are capable of supplying adequate potassium for maximum sugarbeet production. Potassium is important for the function of the stomata, pore-like openings of the plant leaves, through which transpiration of water and uptake of gaseous carbon dioxide occurs. Adequate potassium nutrition of the plant is necessary to ensure the integrity of the water economy within the plant. Early symptoms of potassium deficiency include a tanning and leatherness of edges of recently matured leaves. More severe deficiency symptoms are a severe interveinal leaf scorch and crinkling that proceeds to the midrib.

Less than five percent of the soils in the region would be expected to need potassium. Soil tests measure exchangeable and soluble potassium, which is readily available to the plant. Soils which need potassium fertilization can be identified and properly fertilized by following the recommendations in *Table 8.4*.

**Table 8.4**

Potassium fertilizer recommendations

Potassium soil test level (Exchangeable potassium, ppm)	Potash application rate (lb K <sub>2</sub> O/A)
0-39	120
40-74	80
75-124	40
125+	0

## Micronutrient Recommendations

**M**icronutrients applied to sugarbeet rarely increased yields or sugar content in experiments conducted over several years. Visual diagnosis of micronutrient deficiencies in sugarbeet is rather difficult because the deficiency symptoms are quite diffuse. Plant tissue or petiole analysis is required in most instances to positively identify the nutrient that is deficient. Zinc has increased yields in a few experiments where tests indicated low soil zinc content. Soils deficient in zinc can be identified and properly fertilized by following the recommendations in *Table 8.5*.

**Table 8.5**

Zinc fertilizer recommendations

Zinc soil test level	Zinc application rate (lb Zn/A, as inorganic Zn such as zinc sulfate)
Very low and low	10-15
Medium	0
High	0

By Gary L. Hein and Gregory D. Johnson

**I**nsect problems in the High Plains of Nebraska, Colorado, Wyoming, and Montana are not consistent across the region. The most severe pest in many parts of the region is the sugarbeet root maggot; however, in other areas it is of little importance or may not even occur. Insects such as the sugarbeet root aphid and army cutworm will occur throughout the region and occasionally cause significant problems. Some insects are considered serious pests in specific areas of the region (e.g. beet leafhopper in the Big Horn Basin and Yellowstone Valley), but most of the other pest insects are of local importance and most often sporadic in occurrence.

Establishing an insect management program for sugarbeet insects is important to avoid economic losses. Developing such a program requires a good understanding of the biology and life cycle of the insect. In addition, the grower must consider the identification of the insect and its damage, damage potential of the insect, and field scouting procedures and timing. Management options to control the insect can include cultural practices (e.g. irrigation practices, varietal resistance, cultivation, rotation), biological control (e.g. effects of predators and parasites), and chemical control. To avoid unnecessary costs and negative impacts of insecticide use, insect management programs need to include proper pest identification, field scouting techniques and use of economic thresholds.

Insecticide use often is required to keep insect populations below economically damaging levels. Lists of registered insecticides are constantly changing due to registration issues and are not included in this chapter. Updated lists of insecticides for specific insects and registered for use on sugarbeet can be found in the following:

- “High Plains Integrated Pest Management Guide for Colorado, Western Nebraska, Montana and Wyoming” (available on the web at <http://www.highplainsipm.org>)
- University of Nebraska Department of Entomology Website: <http://entomology.unl.edu/entomol/fldcrops/pestipm.htm>

## Seed/Seedling Attacking Insects

### Spinach Carrion Beetle

The spinach carrion beetle, *Silpha bituberosa*, rarely occurs at levels significant enough to cause noticeable damage, and insecticide treatment would seldom be economical.

#### Identification and Life Cycle

Carrion beetles are oval-shaped, horizontally flattened, and dull black with longitudinal raised ridges on the wing covers. The larvae appear slightly flattened and are shiny black with distinct segmentation. The larvae look much like sowbugs or pillbugs, but carrion beetle larvae are capable of moving much faster. The adults spend the winter in the soil in field margins, ditch banks, fence

### Seed/Seedling Attacking Insects

Spinach carrion beetle  
Cutworms  
Flea beetle  
Garden symphylan  
Wireworms

**Unnecessary costs and insecticide applications can be avoided by using proper pest I.D.s, field scouting, and economic thresholds.**

rows and alfalfa fields. They can move into sugarbeet fields early in the spring. Females lay eggs in the soil in May and June and larvae will develop in three to four weeks through early summer. In addition to sugarbeet, they will feed on lambsquarters, nightshade, and alfalfa.

### **Plant Damage and Response**

Both adults and larvae will feed on the leaves of sugarbeet with field borders being most likely to show damage. Feeding damage appears as ragged defoliation near the edges of the leaves with residues of crushed plant tissue at the feeding sites. Larvae will cause the most damage. They are primarily a threat during seedling emergence and establishment when the limited leaf area of the sugarbeet increases the impact of the damage.

### **Management**

Early season scouting should indicate whether these insects are present in great enough numbers to cause significant damage. Once sugarbeet have reached about the four-leaf stage, damage potential would be minimal as plants outgrow additional damage unless populations are extreme.

### **Cutworm**

Cutworms can be a devastating problem in seedling sugarbeet. The most important species of cutworms in this region overwinter as partially grown larvae or eggs and feed extensively early in the spring. Because sugarbeet emerge and grow slowly during early establishment, these actively feeding cutworms can quickly and severely reduce sugarbeet stand. Several species of cutworms can damage sugarbeet in this region, including the army cutworm (*Euxoa auxiliaris*), pale-western cutworm (*Agrotis orthogonia*), dark-sided cutworm (*Euxoa messoria*), variegated cutworm (*Peridroma saucia*), and perhaps others. Of these cutworms, the army cutworm most commonly is found damaging sugarbeet.

### **Identification and Life Cycle**

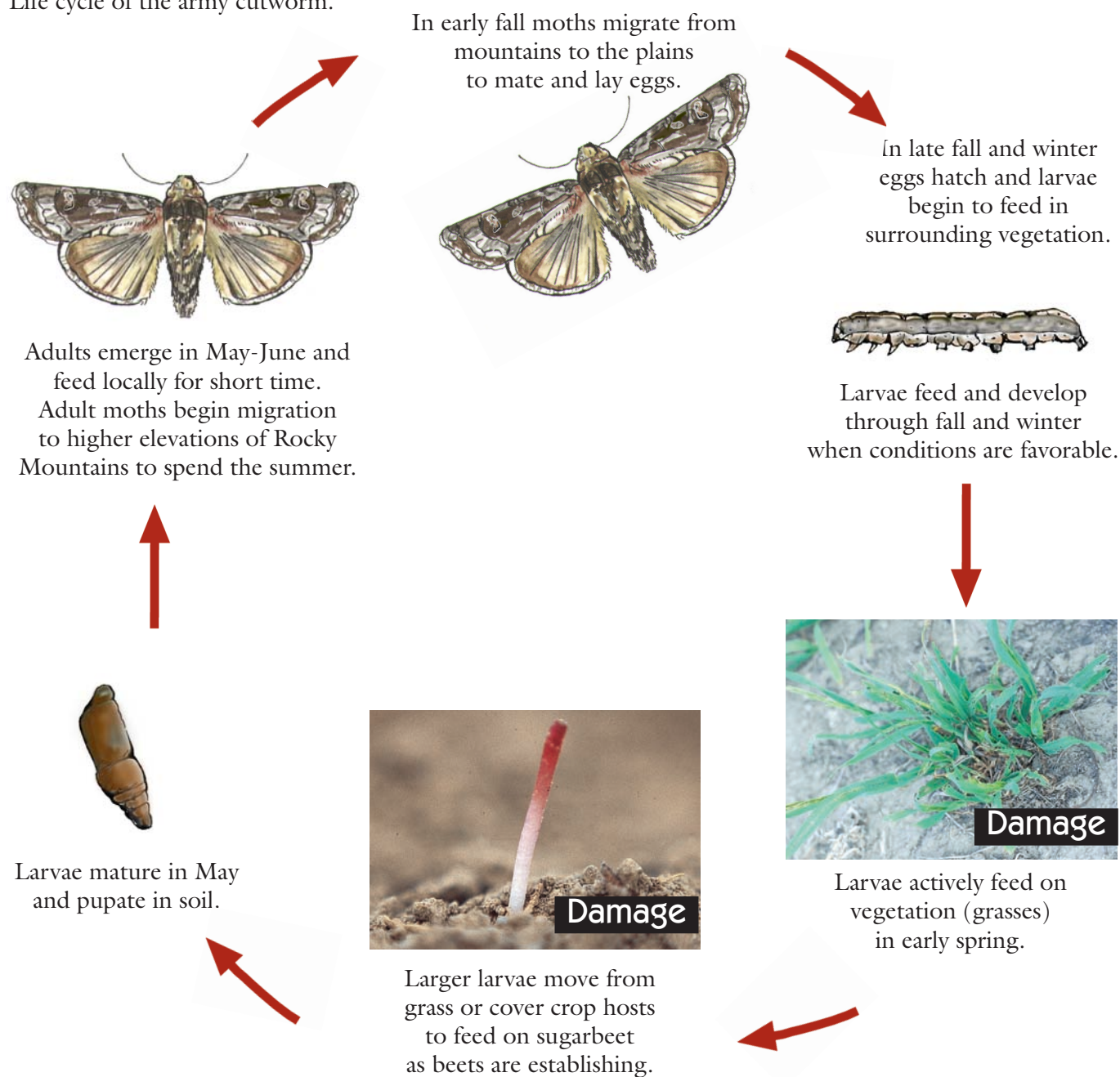
Army cutworm moths have a wing span of about 1 1/2 inches and are typical of the “miller moths” that are commonly observed in the region. In the fall, females are attracted to bare areas such as over grazed pastures, alfalfa stubble, stressed grassy areas, and newly planted or tilled cropland (i.e., winter wheat) and lay their eggs directly in the soil. Females lay from 1000 to 3000 eggs from September until late October. Egg hatch is extended and often occurs shortly after the eggs have been exposed to moisture (i.e., rainfall). The result of this extended egg laying and hatching period is a great variation in larval size within fields the following spring. Larvae continue to feed as long as temperatures are favorable, and partially grown larvae overwinter in the soil. Larval feeding activity resumes in late winter or early spring (February-March) when soil temperatures increase. By late April and May, fully grown larvae will burrow into the soil, create an earthen chamber, and pupate. Adults emerge from the soil in May through early June to complete the life cycle. The adults migrate to higher elevations in the Rocky Mountains for the summer and return in the fall.

Larvae of the army cutworm (*Figure 9.2*) have a pale grayish body color that is spotted with variable white or light markings. The upper surface is lighter with a narrow pale stripe along the center of the back. There is a lighter band



**Figure 9.1**

Life cycle of the army cutworm.



Army Cutworm Pest Scouting Calendar for Sugarbeets

Army Cutworm	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.-Feb.
Larvae									
Adults									
Eggs									
Peak damage									
Treatment period									

**Figure 9.2**

Pale western (top) and  
army cutworms (bottom).

(Photo courtesy of J. A. Kalish,  
University of Nebraska-Lincoln)



along the side of  
the larvae below  
the spiracles. Lar-  
vae can be 1 1/2  
to 2 inches long  
when fully grown.

Perhaps the  
second most im-  
portant cutworm  
in sugarbeet is the  
pale western cut-  
worm (see *Figure*  
9.2). Pale western  
moths begin to  
emerge in late Au-

gust and lay eggs throughout September. The moth flight coincides with tillage and planting of winter wheat. Moths are attracted to areas with loose soil and deposit their eggs in the upper 1/2 inch of soil. Eggs hatch early in the spring when temperatures at the soil surface reach 70°F. This may occur from February through April. The pale western cutworm larva is pale with no distinct markings on its body and can be easily distinguished from other cutworms present early in the spring. When fully grown, the larva is about 1 1/4 inch long. Pale western cutworms feed through the spring and mature in May and early June. Other cutworms that may be found in sugarbeet fields (e.g. dark-sided and variegated cutworms) develop later in the spring and summer and are normally less of a concern to sugarbeet. However, when populations are high, damage can occur to seedling beets and later to larger beets where they can feed on and damage the crown.

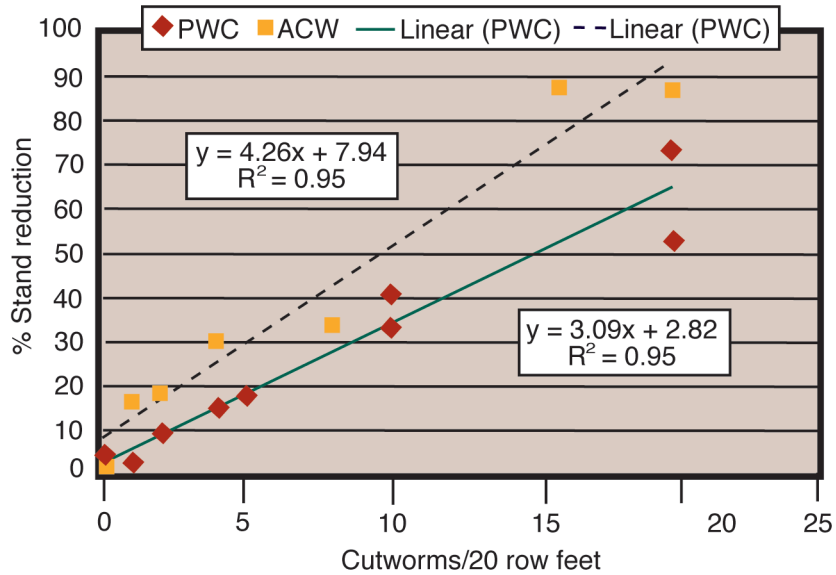
### *Plant Damage and Response*

The army cutworm has an extremely wide host range. It feeds on nearly all field crops including alfalfa, barley, corn, oats, potato, sugarbeet, wheat, many vegetables and a number of grasses. Crops most often economically damaged are winter wheat and alfalfa because often they are the only crops growing in the early spring when army cutworm feeding is at its peak. Sugarbeet are often damaged when cutworms move from adjacent fields or grassy borders into emerging beet fields. More importantly, problems with army cutworms have resulted where winter cereal (primarily winter wheat) cover crops are grown through the winter and sugarbeet are planted directly into the cover crop. When the cover crop is killed the cutworms readily move to feed on the emerging sugarbeet.

The greatest potential for army cutworm damage to sugarbeet occurs in fields where plants are beginning to emerge and establish. At this time, damage can be severe because the insect's consumption rate is high and the plant's biomass is small. Very low densities (1 per 20 row feet) of cutworms can cause stand loss (5-10 percent) at this time (*Figure 9.3*). Damage symptoms at this time are difficult to notice. Often the only sign of cutworm damage is a reduc-

**Figure 9.3**

Relationship between pale western (PWC) and army cutworm (ACW) density and stand reduction in seedling sugarbeet, University of Nebraska, Panhandle Research and Extension Center, Scottsbluff, Nebraska.



tion in stand. The large larvae can consume multiple plants each night, and if present in large enough numbers, they can completely destroy the sugarbeet stand in only a few nights. Damaged plants can be seen by scratching away the soil around the seedling to expose a stub cut back to just below the soil line (Figure 9.4). These plants will not recover because their growing point has been consumed by the cutworm. If plants were able to emerge before the cutworms began feeding or if smaller larvae were present, cutworm damage would appear as holes in the leaves, or perhaps, leaves or entire plants would be cut off (Figure 9.5).

Pale western cutworms also can damage sugarbeet where a small grain cover crop was used. Pale western larvae can survive up to a month without food. If present in the cover crop, they can survive the tillage and planting operations and attack emerging plants.



**Figure 9.4**

The top inch of soil has been pushed away to show how a sugarbeet seedling 'stub' was cut off at soil level by army cutworm.



**Figure 9.5**  
Army cutworm leaf feeding  
on seedling sugarbeet.



### Management

There are few management options available to reduce the severity or damage potential of the army cutworm. Careful field scouting and assessment of the cutworm situation should be the first step. Sugarbeet planted into a

winter cereal cover crop are at a high risk for cutworm damage. Consideration should be given to treating the sugarbeet for cutworms when spraying herbicides to kill the cover crop. Sugarbeet should be scouted early and often during establishment so the extent of infestation and damage can be assessed. Because cutworms are difficult to detect, scouting must include some attention to the progression of emerging plants. If emergence or stand density starts to decline, the problem must be thoroughly evaluated and immediate action taken. In some years, movement of cutworms out of border grasses also can be significant. In these areas scouting should include a check of border grasses for defoliation of new plant growth (see *Figure 9.6*).

**Figure 9.6**  
Army cutworm damage  
(defoliation) to early  
spring grasses found  
in field borders.



The most effective control can be obtained with a layby insecticide. Pyrethroid insecticides are the most effective treatment against cutworms. Only one planting-time insecticide has been shown to be effective on cutworms in sugarbeet. Lorsban 15G will provide reasonable cutworm control when applied at planting on sugarbeet; however, effectiveness will be poor or variable under dry conditions.

Also when applied at planting, this product can have a significant phytotoxic effect on the beet. Placing this product to the rear of the planter press wheel will minimize, but not eliminate, this problem.

### Flea beetle

The most common flea beetle to damage sugarbeet in this region is the pale-striped flea beetle, *Systema blanda*. However, other species of flea beetles may be found damaging sugarbeet. Damage is sporadic, and flea beetle populations are often associated with other crops in the cropping rotation.



### Identification and Life Cycle

The pale-striped flea beetle is about 1/6-inch long with a broad pale-white stripe on each wing cover (*Figure 9.7*). The most distinctive aspect of flea beetles is their ability to jump like fleas. This characteristic makes them rather difficult to see unless they are present in large numbers. Other flea beetles that could damage sugarbeet are somewhat smaller and are uniformly dark in color. Adult flea beetles are most likely to cause problems in May and June as the leaf area of the sugarbeet is limited and the impact of flea beetle defoliation is greatest.

Pale-striped flea beetle larvae overwinter in the soil and feed on seedlings in the spring. They are slender and white with a brown head. As soils warm in the spring they will begin to feed on root tissue.

### Plant Damage and Response

Adult flea beetles produce characteristic shot-holing on the leaves of sugarbeet. These shot holes are round, uniform in size and may range from 1/16 to 1/8 inch in diameter. Damage is most severe during the early season when sugarbeet plants have small leaves. Extensive leaf feeding can eventually kill the leaves and perhaps the whole plant, especially if allowed to damage the growing point of the plant. As sugarbeet add foliage their susceptibility to damage by these insects is lessened.

Pale-striped flea beetle larvae feed on the roots of seedling sugarbeet. Their feeding damage appears like a darkened constriction on the roots, similar to black root (see *page 140*).

### Management

Flea beetle populations can be increased in certain rotations (following alfalfa and dry beans) or if host weed populations such as poverty weed, bindweed, and pigweed are high. Avoid planting sugarbeet after alfalfa or in areas where flea beetle populations were high the previous year. Closely monitor beet fields planted near alfalfa fields or weedy areas as adults may move out of these areas into sugarbeet. In areas where flea beetle problems are more consistent, systemic insecticide treatments (e.g. soil-applied or seed treatment) can be used to reduce problems from these insects.



**Figure 9.7**

Pale-striped flea beetle.

(Photo courtesy of J. A. Kalisch, University of Nebraska-Lincoln)

### Garden Symphylan

Symphylans, *Scutigerella immaculata*, rarely build up to damaging levels. Occurrence in the field is likely to be spotty, however, damage in these spots may be severe.

### Identification and Life Cycle

Symphylans are fast moving soil arthropods that resemble centipedes (*Figure 9.8*). They grow to 3/8 inch long, have long antennae and can have up to 12 pairs of legs. Their entire life cycle is spent in the soil. They will move up and down in the soil depending on soil moisture and temperature.

**Figure 9.8**  
Symphylans in the soil.



#### *Plant Damage and Response*

Symphylans feed on decaying vegetable matter and small root hairs on the plant. Roots can be severely pruned with few secondary roots remaining. This stubby root appearance may resemble chemical injury. Damage can result in severe stunting and plant death and most often it is confined to localized spots or patches.

#### *Management*

Symphylans often are associated with fields that have a history of heavy manure use or very high organic matter. Deep vigorous tillage

may reduce symphylan numbers, but severe infestations may require fumigation or a pre-plant broadcast insecticide for adequate control.

### **Wireworm**

Wireworm damage in sugarbeet is difficult to predict because it depends on the inherent population of wireworms in the soil and on the environmental conditions that occur during sugarbeet emergence and establishment. Serious damage does not occur frequently.

#### *Identification and Life Cycle*

Several species of wireworms may cause damage in sugarbeet fields. Wireworms are slender, hard-bodied, yellowish larvae up to 1.5 inches long (*Figure 9.9*). Wireworms have extended life cycles that last two to five years depending on the species. Adult wireworms are attracted to grass hosts where they will lay their eggs; therefore, rotations that include grasses (including cereal crops) and areas with substantial grass weed pressure will increase the potential for wireworm problems.

**Figure 9.9**  
Wireworm larvae and damaged (cut off) sugarbeet seedling.



#### *Plant Damage and Response*

Wireworms can attack germinating seed and destroy them before they are able to emerge. However, sugarbeet normally are planted while soil temperatures are too cool for optimum wireworm activity. Wireworms move up and down in the soil depending on the temperature and moisture in the soil. As the sugarbeet emerge

and soil temperatures rise to 50-55°F, wireworms move nearer the soil surface and begin feeding. At this time the wireworms will feed on the tap root and secondary roots of these small plants at a depth of only a few inches. This feeding may result in severed tap roots and cause the plant to wilt and die (*Figure 9.9*). Verification of the cause of this damage is important as several other pests (insects and disease) can cause this type of damage. Wireworm feeding on larger beets can result in root scarring that is of little importance (*Figure 9.10*). Later in the season as the soils continue to warm and the surface dries, the wireworms will move deeper in the soil and their impact on plants will be dramatically lessened. Severe wireworm damage is often spotty in the field.

### Management

Wireworm damage is difficult to predict, but several factors can be used to determine the damage potential from wireworms. Field history is an important factor. Wireworms most often cause damage in fields where damage has occurred in the past. Also, fields with a history of grass (recent sod or cereal crop) or grassy weed problems are at a higher risk. Because of the multiple year life cycle of this insect, risk of damage may last for several years. One major factor in determining the risk of wireworm problems is the weather. If soil temperature and moisture conditions remain optimum, the risk of wireworm will increase dramatically.

In fields with a high risk of wireworm damage, wireworms can be controlled with seed treatments or with the use of soil insecticides. In other crops the best wireworm control results from the use of soil insecticides applied in the furrow; however, sugarbeet are very sensitive to organophosphate insecticides applied at planting. These products should not be applied in the furrow even for control of wireworms.



**Figure 9.10**  
Wireworm feeding damage on larger sugarbeet.



## Foliage Feeding Insects

Aphids  
Beet leafhopper  
Blister beetle  
False chinch bug  
Grasshoppers  
Spinach leafminer  
Lygus bug  
Spider mite  
Webworm  
Late season defoliators

## Foliage Feeding Insects

### Aphids

Across the region aphids are not a common problem in sugarbeet. Aphid presence in sugarbeet will primarily manifest itself in the occurrence of viruses (beet western yellows and beet mosaic viruses) that the aphids are capable of transmitting. These viruses can be found in the region but are seldom of any consequence. A newly identified virus, beet chlorosis virus, has been found in Colorado. The vector for this disease is unknown, but aphids could be involved in its transmission.

### Identification and Life Cycle

The green peach aphid, *Myzus persicae* (Figure 9.11), is the most likely aphid to transmit viruses to sugarbeet in the region. Wingless forms are tear-dropped shaped and light green to light pink in color. Winged adults will be darker with a brown to black thorax and a greenish abdomen. Overwintering of the green peach aphid is not well understood, but if it does overwinter in the region, it would overwinter as eggs on *Prunus* species (various types of plum and cherry). A spring generation would occur on the overwintering host, and winged aphids would leave this host in early summer (June) in search of numerous summer hosts, including sugarbeet.

**Figure 9.11**

Wingless and winged green peach aphids.

(Photo courtesy of J. A. Kalisch, University of Nebraska–Lincoln)



**Figure 9.12**

Bean aphid.

(Photo courtesy of Larry Godfrey, University of California at Davis)



A second aphid found in sugarbeet in the region is the bean aphid, *Aphis fabae*. The bean aphid (Figure 9.12) is blue-black in color, and overwinters in the egg stage on *Euonymus* bushes. These aphids also will spend a generation in the spring on their overwintering host, and then move to sugarbeet and other summer hosts.

### Plant Damage and Response

Aphids suck sap from the plant, causing leaf curling and puckering. Severely damaged leaves may turn yellow. The most important aspect of aphid presence in sugarbeet



is its ability to transmit viruses (see *Chapter 11, Disease Management*). The green peach aphid is the most effective vector of western yellows and beet mosaic viruses. Bean aphids, however, are more likely to cause direct plant damage to sugarbeet.

### Management

The diseases that result from aphid-transmitted viruses do not occur often and are impossible to predict. We understand very little about the life cycle of the green peach aphid and the bean aphid in the region. Treatments to control virus transmission are not likely to be effective. Treatments for direct aphid damage should only be considered if leaf symptoms (curling, stunting) are present on plants less than 8-12 weeks old and active aphid colonies are present.

### Beet Leafhopper

The beet leafhopper, *Circulifer tenellus*, is the vector of curly top virus. In the Big Horn basin area of Wyoming and the Yellowstone Valley of Montana, curly top has caused severe economic losses when sugarbeet were infected in epidemic proportions. Curly top virus may also occur sporadically throughout the High Plains sugarbeet growing region. The virus has an extensive crop and weed host range represented by at least 300 species in 44 families. Permanent breeding grounds for the beet leafhopper are areas with low annual precipitation (less than 10 inches), low humidity and desert type vegetation. Beet leafhoppers require a sequence of succulent hosts that they utilize through the winter and spring to survive on when field crop hosts are not available.

### Identification and Life Cycle

Proper identification of the beet leafhopper is essential to correctly estimate population densities. The beet leafhopper (*Figure 9.13*) is a small insect (0.12 inch long by less than 0.040 inch wide) that is very active at high temperatures. Its color varies from insect to insect and from season to season. The spring brood is generally light brown to lemon-green; summer and fall broods are tan to variably mottled; and overwintering forms are tan and mottled.

The beet leafhopper can be tentatively identified by the presence of a slightly roof-shaped face that is absent of clearly defined spots (*Figure 9.14*). In addition, when viewed through a microscope, the terminal abdominal segments of the male are square-shaped (not round or triangular) and those of the female have a semi-circular appearance. On reasonably warm days (60°F or warmer) the beet leafhopper is more active than other leafhoppers commonly found in the region.

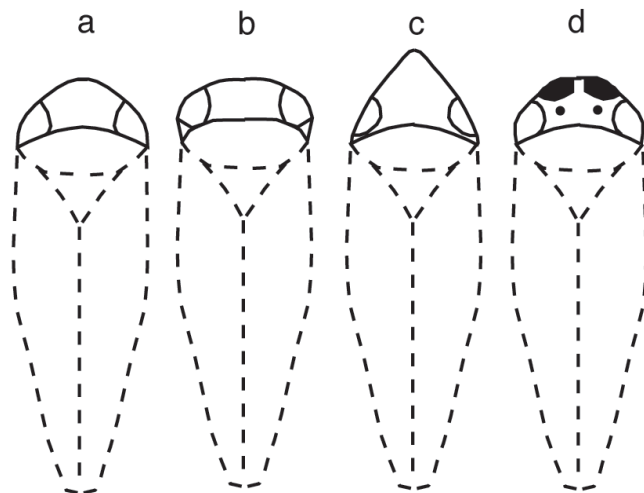


**Figure 9.13**

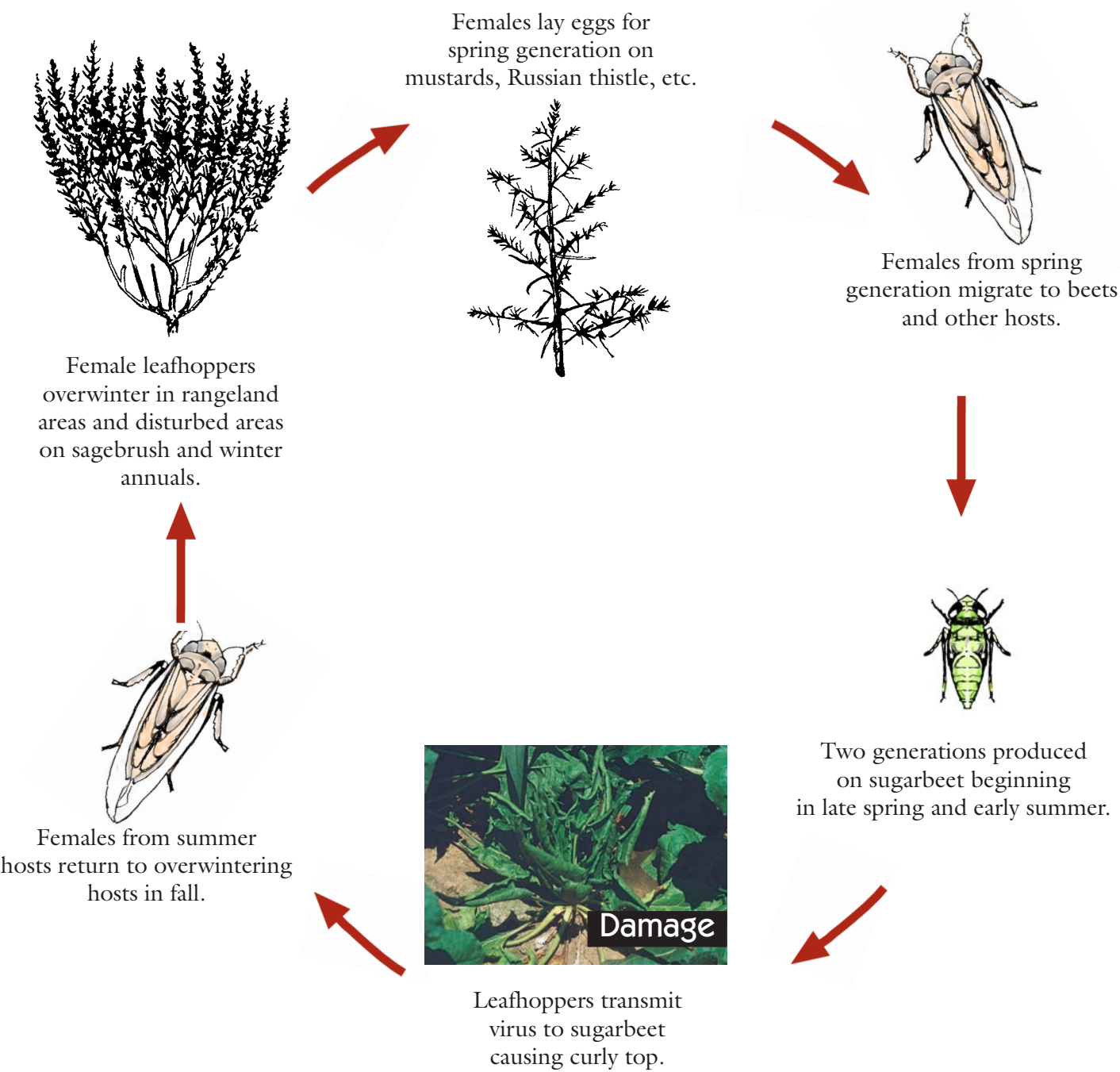
Sugarbeet leafhopper.  
(Photo courtesy of Larry Godfrey,  
University of California  
at Davis)

**Figure 9.14**

Identification of sugarbeet leafhopper by comparative shape; beet leafhopper (a) has moderately pointed face compared to rounded (b) or sharply pointed (c) face, and has no distinct spots on head (d), as other leafhoppers may.  
(Courtesy of University of Wyoming CES Bulletin B-978)



**Figure 9.15**  
 Lifecycle of the beet leafhopper.



Beet Leafhopper Pest Scouting Calendar for Sugarbeets

Beet Leafhopper	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.-Feb.
On overwintering hosts									
On sugarbeets									
Disease transmission									
Treatment period									

Beet leafhopper females overwinter on hosts found in rangeland and in disturbed areas, such as sagebrush, salt bush, greasewood, filaree, mustards, and Russian thistle. In the spring, the females will lay eggs for an initial generation on hosts available at this time, primarily mustards, kochia, hoary cress, hal-ogeton, and Russian thistle. Beet leafhoppers prefer sparse vegetation that allows maximum sunlight and heat to penetrate through the plant canopy. After the initial generation has been completed, adult leafhoppers will move to summer hosts, which include sugarbeet. They will complete two generations on these summer hosts before moving back to their overwintering hosts in the fall.

### *Plant Damage and Response*

Beet leafhopper does not cause significant direct damage to the sugarbeet, but the transmission of curly top virus can result in loss. Curly top virus infections that begin during the early growth stages of sugarbeet can cause complete or nearly complete losses. Curly top symptoms include the rolling inward and puckering of the leaves along with the swelling and prominent appearance of the veins. Severe infections will result in stunting and possible death of the plants (see *Chapter 11, Disease Management*).

### *Management*

In areas where the beet leafhopper and curly top virus are a problem, several cultural practices can reduce the potential for leafhopper buildup and damage potential to the crop. Plant as early as possible to insure the sugarbeet plants are at a later growth stage and have a greater tolerance to the virus prior to infection during the season. Plant tolerant varieties in areas with a history of curly top virus. These varieties will limit the impact and help to avoid major losses to the disease. Areas around fields, machinery yards and roads should be kept free of host plants for the beet leafhopper. In the Big Horn Basin the primary infestations initially are from areas near sugarbeet fields. In high risk areas insecticide can be added to herbicide sprays when treating weedy areas around sugarbeet fields.

It is important to monitor the beet leafhopper population to determine if control measures are justified. Sensitive tests have been developed for curly top detection, and it is now possible to identify curly top virus sources. Test results can be used to determine the potential role of virus sources in disease development and crop loss. Standardized collection methods must be used to accurately monitor beet leafhopper populations and determine sources of virus. A Wyoming Cooperative Extension Publication entitled “Sugarbeet Curly Top Virus and the Beet Leafhopper” (Publ. No. B-978) gives sampling methods and information on the proper techniques and procedures for leafhopper and virus host sampling.

Leafhoppers can be collected with a sweep net. Sampling must be done only when air temperatures are 60°F or greater to insure adequate leafhopper activity. Determining the leafhopper density will help to establish the virus risk level in the area. Resistant varieties are damaged less by the virus; however, if plants are smaller than the 12-leaf stage, leafhopper densities in adjacent weedy areas are more than one leafhopper per 10 sweeps, and more than eight percent of the leafhoppers are viruliferous, there is still a significant risk to resistant varieties.

## Blister Beetle

Several species of blister beetles will feed on sugarbeet. Four of the most common blister beetles found to feed on sugarbeet are the black, ash-gray, spotted and the striped. Economic infestations of these insects are rare, but isolated infestations may occur in years with high grasshopper populations.

**Figure 9.16**

Ash gray blister beetle.

(Photo courtesy of J. A. Kalisch,  
University of Nebraska–Lincoln)



### Identification and Life Cycle

Blister beetles are soft-bodied insects with a slender cylindrical shape (*Figure 9.16*). They range in length from about 1/3 to 3/4 inch. Blister beetle larvae are predacious on grasshopper eggs and are therefore beneficial.

In years when grasshopper populations are high, blister beetle adult populations also will be high.

### Plant Damage and Response

Blister beetles often feed in large aggregations which can result in rapid defoliation of the host plants in spots in a field. Total leaf defoliation can occur, leaving only the midribs of the plants; however, these infestations are generally limited to small patches.

### Management

Scouting of sugarbeet fields and insecticide treatments of damaging populations is necessary to manage this occasional pest.

## False Chinch Bug

False chinch bug, *Nysius raphanus*, can appear in dramatic numbers and cause damage to sugarbeet, but it rarely reaches damaging levels and its distribution in fields is nearly always patchy and limited.

**Figure 9.17**

False chinch bug.

(Photo courtesy of Phil Sloderbeck,  
Kansas State University)



### Identification and Life Cycle

The adult false chinch bug is dark gray and looks like a small (1/8 inch) lygus bug. It overwinters as an adult or nymph (*Figure 9.17*) sheltered in debris. It is often found with winter annual mustards on which it feeds during the winter and early spring. The false chinch bug will undergo multiple generations, each taking about three to four weeks. Adults are strong fliers

and can readily move from host to host or field to field. Peak numbers will occur in July and August.



### Plant Damage and Response

False chinch bugs can occur in extremely high numbers. They feed by sucking sap from the plant, which can cause rapid wilting or plant death. They tend to congregate their feeding activity on individual or small groups of plants.

### Management

Significant field wide damage will seldom occur from this insect. Damage potential would be greatest near infestations of mustards. Insecticidal control of this insect in sugarbeet would seldom be warranted, especially on a field wide basis.

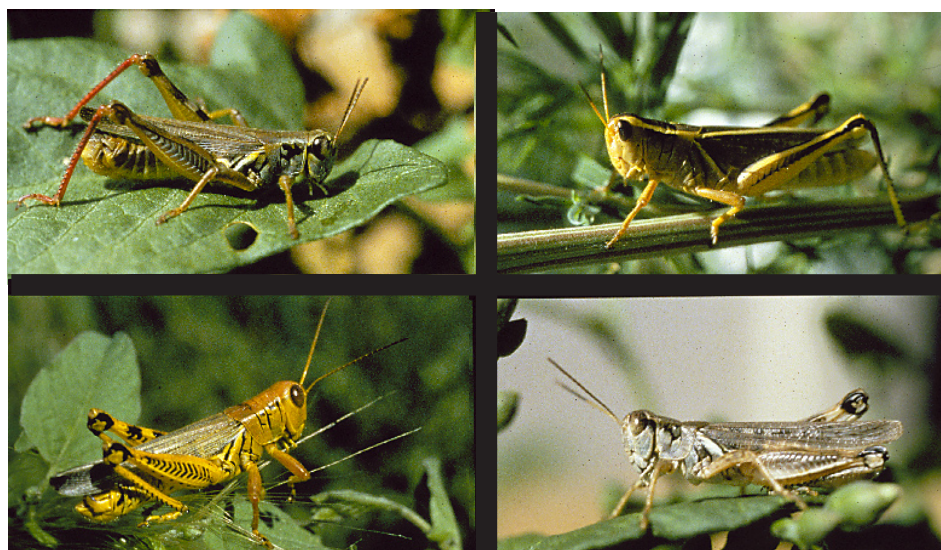
### Grasshopper

Four species of grasshoppers (*Figure 9.18*) are mainly responsible for damage to field crops. These are the differential, two-striped, red-legged and migratory grasshopper. These grasshoppers will feed on a wide range of hosts, including sugarbeet.

### Identification and Life Cycle

All these species of grasshoppers overwinter in the egg stage. The earliest hatching grasshopper species is the two-striped grasshopper which normally begins to hatch in May. The other species will begin to hatch over the next three to four weeks and the hatch for each species will continue for over a month.

Extended cool (less than 65°F) and rainy weather during hatching can cause severe mortality of the young nymphs and can substantially reduce the buildup of grasshopper populations. Grasshoppers will develop through five immature stages before they become adults. This development will take about six to eight weeks. Adult grasshoppers have wings and this increases their ability to move longer distances beginning in late June and July. Egg laying will begin in mid to late summer and continue until the grasshoppers are killed off by frost in the fall. Grasshopper feeding activity begins during the daytime when temperatures rise above 70°F.



**Figure 9.18**

(Clockwise from upper left): Four major species of crop pest grasshoppers; redlegged, two-striped, migratory, and differential grasshoppers. (Photo courtesy of John Capinera, University of Florida)

**Figure 9.19**

Early season damage to sugarbeet by grasshoppers.



### *Plant Damage and Response*

Damage is usually limited to field margins as the grasshoppers move out of adjoining hatching areas. Grasshoppers damage sugarbeet by consuming the leaves. Unusually severe infestations can result in grasshopper feeding into the newly emerged leaves and direct feeding damage to the growing point. This damage can occasionally result in death of the plant. In mid-summer, the increased mobility of adult grasshoppers coupled with the drying down of original food sources increases the damage potential to sugarbeet and other field crops.

In years with very warm temperatures during winter and early spring, a hatch of grasshoppers in early May can threaten young sugarbeet seedlings (*Figure 9.19*). Grasshopper nymphs move out into sugarbeet fields and destroy the young sugarbeet by consuming the cotyledons and the growing point of the small plants. If grasshopper densities are great, damage to these emerging fields can proceed rapidly and result in nearly complete stand loss, particularly near the borders.

### *Management*

Untilled areas are the major hatching environment for grasshoppers since tillage reduces egg survival. Untilled areas with a mixture of both grasses and broadleaf plants are particularly attractive to grasshoppers. Eliminating broadleaf plants and establishing grass cover in these areas will significantly reduce their appeal to grasshoppers.

If grasshopper infestations along field margins are defoliating sugarbeet extensively, insecticide treatments would be warranted. More than eight grasshoppers per square yard in the field margin or more than 20 per square yard in the border area would likely warrant control. Adult grasshoppers are much more difficult to control than the smaller nymphs, so in years when extremely high grasshopper numbers are present, early treatment of hatching areas before the grasshoppers become adults may reduce later impact.

## Spinach Leafminer

The spinach leafminer, *Pegomya hyoscyami*, can be readily found in most sugarbeet production areas; however, it seldom will reach levels of economic importance.

### Identification and Life Cycle

The leafminer overwinters in the soil in the pupal stage. Adult flies will emerge in May and seek out sugarbeet to lay their eggs. The adults are gray and smaller and thinner than a house fly. The larvae are white maggots and are always present in the mine inside the leaf. During the course of the year they will go through two or three generations, but the first generation is the most important because the sugarbeet foliage is most limited at this time. The females lay their eggs on the underside of sugarbeet leaves. When the eggs hatch the larvae will feed in the area between the upper and lower surfaces of the leaf. Larval development within the leaf will only last for about two weeks after which the maggot will move to the soil and pupate. The pupal period will last for two to three weeks after which the flies will emerge to begin a new generation.

### Plant Damage and Response

While the larvae are small they create narrow, winding tunnels in the leaves that are visible as water soaked or whitish areas. As the larvae increase in size and in feeding consumption, the feeding areas appear as large irregular blotches on the leaves. These large leaf mines will dry up and darken, giving the plant a very ragged appearance (*Figure 9.20*).

### Management

Leafminers attack sugarbeet early in the season when leaf area is limited; however, the leaf area of a sugarbeet with these mines is seldom great enough to warrant treatment. The area of the mines will increase until the maggots move out of the leaf to pupate. At this time the sugarbeet plants begin to increase in size, and by the time the next generation of leafminers begins, the size of the beets limits the impact of the insect. An additional factor limiting leafminer damage is a potentially high rate of parasitization of the larvae near the end of the first generation. Insecticidal control of the first generation can be obtained by systemic soil insecticides (e.g. Counter) or seed treatment (Gaucho).



**Figure 9.20**  
Spinach leafminer damage to sugarbeet.



## Lygus Bug

Lygus bug, *Lygus spp.*, is a term given to a group of insects that are related and have a similar appearance and life cycle. These insects feed primarily on flowers and developing seeds, but they can damage sugarbeet leaves. Economic damage from this insect would be rare.

**Figure 9.21**

Lygus bug adult.

(Photo courtesy of J. A. Kalisch,  
University of Nebraska–Lincoln)



### Identification and Life Cycle

Lygus bugs are green to brown in color with black and yellow markings. They are roughly 1/4 inch long and have a triangular patch on the back between the wings (Figure 9.21). They overwinter as adults in debris in and around fields. They require approximately one month to complete their development so multiple generations will occur each year. Lygus bug

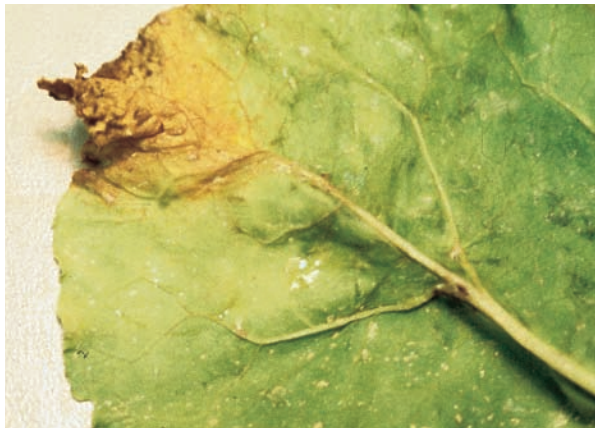
adults will readily move from field to field and are most frequently found in alfalfa fields.

### Plant Damage and Response

Feeding from the lygus bugs can cause yellow discoloration and distorted growth (puckering) at the leaf tips (Figure 9.22). Extensive feeding can result in severe damage to the heart leaves and stunting of the plant. Young leaves that are just developing are most susceptible to lygus feeding. When adjacent alfalfa fields are cut, lygus bugs are apt to move into sugarbeet fields to feed.

**Figure 9.22**

Lygus bug damage  
at sugarbeet leaf tip.



### Management

Lygus bug presence is rarely severe enough to justify an insecticide application. In this region it has been limited to a few isolated plants in the field. North Dakota State University has established a crude treatment threshold of a third of the plants infested with one or more lygus bugs.

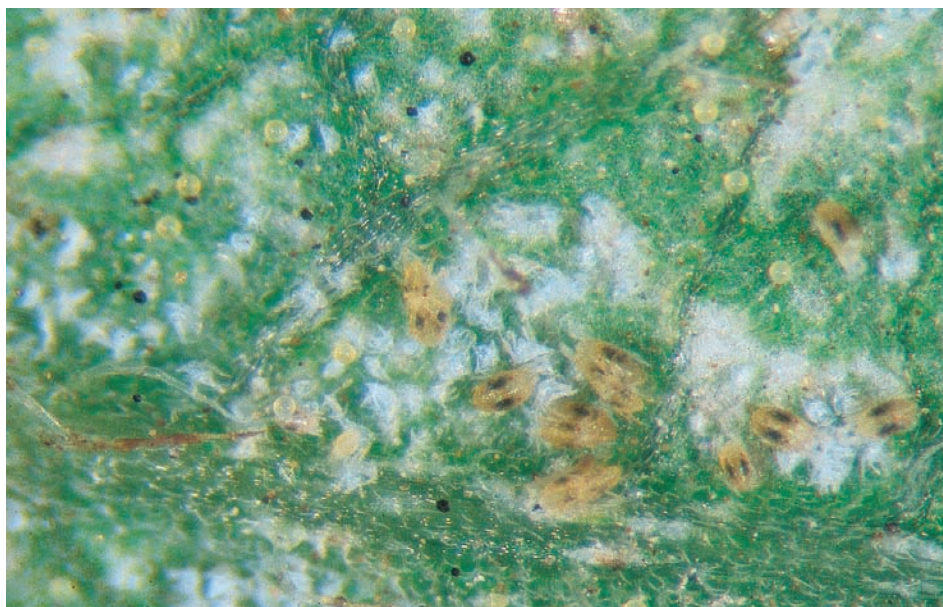
## Spider Mite

The two-spotted spider mite, *Tetranychus urticae*, is not a common pest of sugarbeet, but it can be found at times when conditions are dry and rainfall is severely limited.

### Identification and Life Cycle

Two-spotted spider mites (Figure 9.23) are tiny, eight-legged mites that are yellowish with two spots on either side of the body. In the fall, females





**Figure 9.23**  
Two-spotted spider mite  
and damage.

turn orange-brown and overwinter in protected areas on and around their host plants. When temperatures warm in the spring they again become active and when warm can reproduce at very rapid rates with new generations in as little as 10 days. Populations peak in July and August.

#### *Plant Damage and Response*

The mites feed on the underside of leaves by sucking sap from the plant. This feeding can cause white flecking on the leaves. Severe damage on stressed plants can result in leaf yellowing and death and reduced plant vigor.

#### *Management*

Mite damage to sugarbeet is not common since beets are not the most preferred host for the mites. Mites are much more common on corn, alfalfa and some broadleaf weeds. Cutting adjacent alfalfa or weedy areas under dry conditions can trigger mite movement into sugarbeet. Numerous natural enemies, both insects and mites, usually control spider mite populations; however, under dry and warm conditions, mite populations may increase too fast for natural enemies. Rainfall and sprinkler irrigation act to dislodge mites from the plants, so periods of very low rainfall will increase the potential for mite problems developing. Insecticidal control is seldom necessary for mites in sugarbeet.

#### **Webworm**

Three species of webworms (sugarbeet, alfalfa, and garden webworms) can be found to feed on sugarbeet. Their occurrence is not very common, but when present in large numbers the damage can be very severe.

#### *Identification and Life Cycle*

Webworms overwinter as mature larvae or pupae in the soil. Adult moths will emerge in May and begin laying eggs on sugarbeet. Eggs are laid singly or in small groups on the underside of leaves. Lambsquarters and Russian thistle are especially attractive for egg laying. There are usually two generations of webworms with the first generation larval feeding period in June and the second in late July or August.

**Figure 9.24**

Sugarbeet webworm.

(Photo courtesy of Frank B. Peairs,  
Colorado State University)



The early instar beet webworms, *Loxostege sticticalis*, are light in color and feed within webs near the base of the leaves. Later instars (Figure 9.24) become olive green and have a dark stripe down the center

of the back and three circular spots on each segment on either side of the center stripe. From each of these spots projects a long hair. The alfalfa webworm, *Loxostege commixtalis*, has similar spots with protruding hairs, but the stripe on the back is broad, light in color, and covering nearly the entire area between the spots. Both the beet and the alfalfa webworms can reach about 1 1/2 inches in length. The garden webworm, *Achyra rantalis*, is the least common of the webworms and only reaches a maximum length of 1 inch. It has similar markings to the other webworms.

#### *Plant Damage and Response*

When webworm larvae hatch they feed on the lower surface of the leaves. These early instars can not feed completely through the leaves, resulting in a pitting on the lower leaf surface. Larval consumption rates in later instars increase dramatically and the larvae begin to feed completely through the leaves, causing damage to increase rapidly. Substantial defoliation can occur in a short time. This increase in defoliation is especially striking because the early instar feeding often goes unnoticed. Heavy infestations can result in only the midveins remaining on the plant (Figure 9.25). Also, heavy feeding can result in the growing point being damaged. The greatest potential for damage will occur during the second generation, because of good survival and reproduction of the first generation.

**Figure 9.25**

Sugarbeet webworm  
leaf defoliation damage.





### Management

Weed control in sugarbeet fields can be an important factor in the occurrence of webworm populations as female webworms are attracted to weeds, such as lambsquarters or Russian thistle, for egg laying. Detection of developing populations can lead to prevention of the rapid defoliation of sugarbeet by the larger larvae. Scouting for the early signs of an infestation are important. Insecticide control would be warranted if significant defoliation has occurred and larvae are still actively feeding.

### Late Season Defoliators (zebra caterpillar, woolly bear caterpillars)

The zebra caterpillar, *Melanchra picta*, and the yellow woolly bear caterpillar, *Spilosoma virginica*, are two insects that often are present late in the season in sugarbeet

fields. These insects feed on the foliage of sugarbeet, but rarely are present in great enough populations to cause significant damage. The zebra caterpillar is strikingly colored yellow and black (Figure 9.26). Woolly bear caterpillars are covered by long fuzzy hairs and range in color from black or brown to white (Figure 9.27). Woolly bears are most often noticed late in the season as they scurry about apparently looking for over-wintering sites.



**Figure 9.26**

Late season defoliator, zebra caterpillar.

(Photo courtesy of J. A. Kalisch, University of Nebraska-Lincoln)



**Figure 9.27**

Late season defoliator, yellow woollybear.

(Photo courtesy of J. A. Kalisch, University of Nebraska-Lincoln)

Both of these insects feed on the sugarbeet leaves later in the season. This late season feeding will have little impact on sugarbeet yield unless defoliation levels become very extensive. Economic injury levels for defoliation of sugarbeet would range from 15 percent total leaf area lost in early August to perhaps 35 percent by early September.

## Root Feeding Insects

Sugarbeet root aphid  
Sugarbeet root maggot  
White grub

## Root Feeding Insects

### Sugarbeet Root Aphid

Sugarbeet root aphids, *Pemphigus betae*, are a common problem in sugarbeet fields in this region. Their life cycle is an important factor in their pest status. Resistant varieties and cultural practices are the main management tools for this insect.

#### Identification and Life Cycle

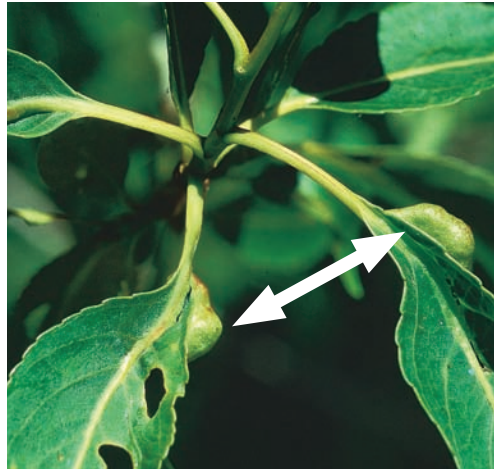
Sugarbeet root aphids have a complicated life cycle that includes an overwintering generation on narrowleaf cottonwood trees. In the fall, a sexual

reproducing generation produces overwintering eggs on the narrowleaf cottonwood. These trees do not occur in the plains, but are the major species of tree growing along river and dry creek beds at higher elevations above 4,000 to 5,000 feet. During the rest of the year all aphid reproduction is done asexually by females which give live birth to their young. In the spring, the overwintering eggs hatch and the aphids seek expanding cottonwood leaves on which to feed. This early feeding on the expanding leaves results in the development of a gall

(Figure 9.29) at the base of the leaf. Within this gall the female aphid raises a colony of winged aphids. When mature these winged aphids (summer migrants) leave the cottonwood trees and fly to sugarbeet fields. With the aid of air mass movements these migrants can travel long distances. This migration occurs from about mid June through mid July depending on the latitude and elevation.

**Figure 9.29**

Sugarbeet root aphid gall on narrowleaf cottonwood leaf.



**Figure 9.30**

Sugarbeet root aphid on beet root.

(Photo courtesy of J. A. Kalisch, University of Nebraska–Lincoln)

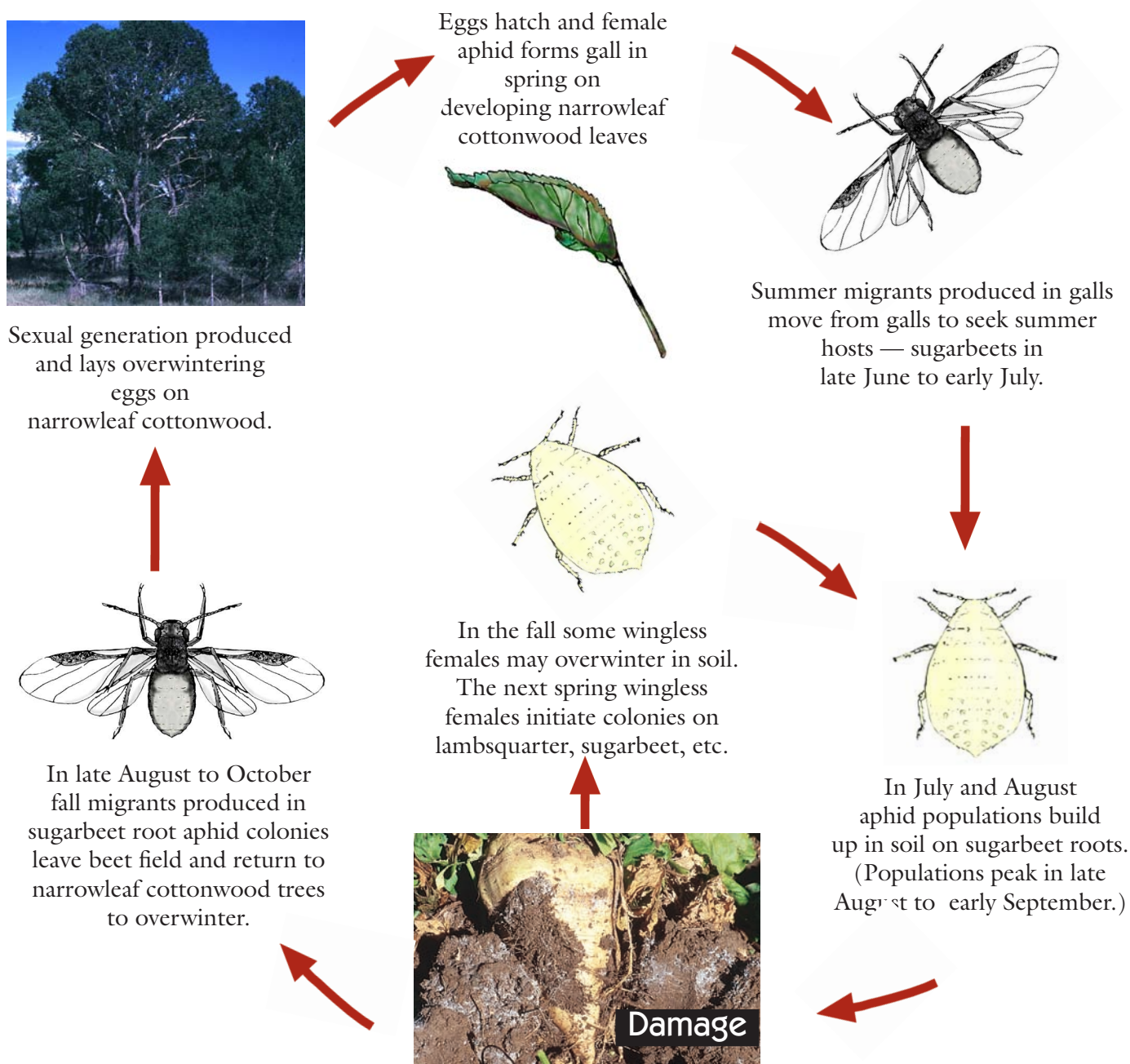


The winged aphids arriving in the sugarbeet fields establish colonies on the sugarbeet roots, and if conditions are right, large colonies develop on the roots. Subsequent generations remain wingless. The aphids on the roots (Figure

9.30) are yellowish white, broadly oval in shape, and secrete a white waxy mate-



**Figure 9.28**  
Lifecycle of the sugarbeet root aphid.



**Sugarbeet Root Aphid Pest Scouting Calendar for Sugarbeets**

Sugarbeet Root Aphid	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.- Feb.
Tree Cycle									
Beet Cycle									
Peak Damage									
No Practical Treatment Options									

**Figure 9.31**  
Sugarbeet root aphid colony with white waxy material.



**Figure 9.32**  
Late season sugarbeet root aphid colony on beet roots.



rial that gives the aphid colonies a distinctive white ‘moldy’ appearance (*Figure 9.31*). Several generations of aphids will be produced on the beet roots, with populations peaking in late August and early September.

Beginning in late August or early September, winged forms of aphids (fall migrants) are produced in the root colonies (*Figure 9.32*). These winged aphids fly out of the beet fields and back to the mountains to establish an overwintering generation on the narrowleaf

cottonwoods. Some root aphids will remain in the soil in the fall and overwinter. These aphids are capable of beginning new infestations on sugarbeet or other host weeds (lambsquarters and pigweed) the following spring; however, these aphids are not winged, their movement is limited, and they are not likely to move to new sugarbeet fields. Avoiding a close rotation of sugarbeet and controlling lambsquarters and pigweed in rotated crops will lessen the potential for problems from root aphids that overwinter in the soil.

### *Plant Damage and Response*

Root aphids feed primarily on the secondary roots of the sugarbeet; however, heavy infestations may be found covering the surface of the beet. Their feeding interferes with nutrient and water uptake and transport. Severe infestations in association with plant stress (i.e. drought) can cause leaf yellowing and wilting. Root aphid damage will result in reduced sugar percentage and tonnage losses to sugarbeet. Recent research in this region indicates that even moderate populations of root aphids, where no above ground symptoms are evident, can result in significant sugar losses (up to 30 percent) on susceptible varieties. Additional stress, such as drought or disease, will increase the impact of the aphids.

## Management

The best option for managing the sugarbeet root aphid is the use of resistant varieties. Recent testing of sugarbeet varieties has shown that many varieties have excellent resistance to the aphid in the field, and susceptible varieties can be severely impacted by the presence of aphids. Most sugarbeet seed companies have lines with excellent resistance to the aphid. Testing has been done to determine resistance levels for regional varieties; however, not all varieties grown in the region have been evaluated. Sugar company or seed company representatives should have the most current information on varietal responses to root aphids. If varieties are showing a considerable presence of aphid colonies in the fall as indicated by the extensive presence of the white waxy material in the colonies and sugarbeet yield or quality is reduced, these varieties should be avoided, if possible. In determining varietal response to aphids, it is important to inspect multiple beets. Some varieties show a segregating response where individual plants will vary in their resistance to the aphid. Some of these varieties have been shown to have significant levels of resistance.

Cultural practices also will reduce the risk of problems from the sugarbeet root aphid. Avoiding a close rotation of sugarbeet and maintaining good control of lambsquarters and pigweed in rotated crops will lessen the potential for root aphids overwintering in the soil. If this is done, reinfestation will need to occur from migration from narrowleaf cottonwoods. Spring migrations to sugarbeet fields throughout the region are likely to occur each year, although the level of migration may vary from year to year. The extent of the problem will depend on several factors that affect both aphid survival through the winter and spring and the weather patterns during and following migration. Proper irrigation during the latter half of the season will reduce stress on the sugarbeet plants and reduce the impact of the aphid. Of particular importance is late season irrigation (late August through September) when aphid populations are at their peak.

There are currently no registered chemical controls that are effective in consistently controlling sugarbeet root aphids.

## Sugarbeet Root Maggot

The sugarbeet root maggot, *Tetanops myopaeformis*, is the most severe insect pest of sugarbeet in many parts of the High Plains region. Infestations begin in late spring and can reduce plant vigor and stand, resulting in lower yields. Effective management of this insect requires knowledge of the insect's life cycle and information about the current population level.

### Identification and Life Cycle

Sugarbeet root maggot adult flies (Figure 9.33) are similar in size and appearance to the house fly (about 1/4 inch). Unlike the house fly, the body is shiny black with few hairs. The wings of this fly are transparent with a smoky-brown patch located on the front of the wing about one-third the distance from the wing base. Also, the legs have yellowish-white bands on the next to last segment ("ankles"), with the rest of the leg being black. The females have pointed abdomens and the males have rounded abdomens.

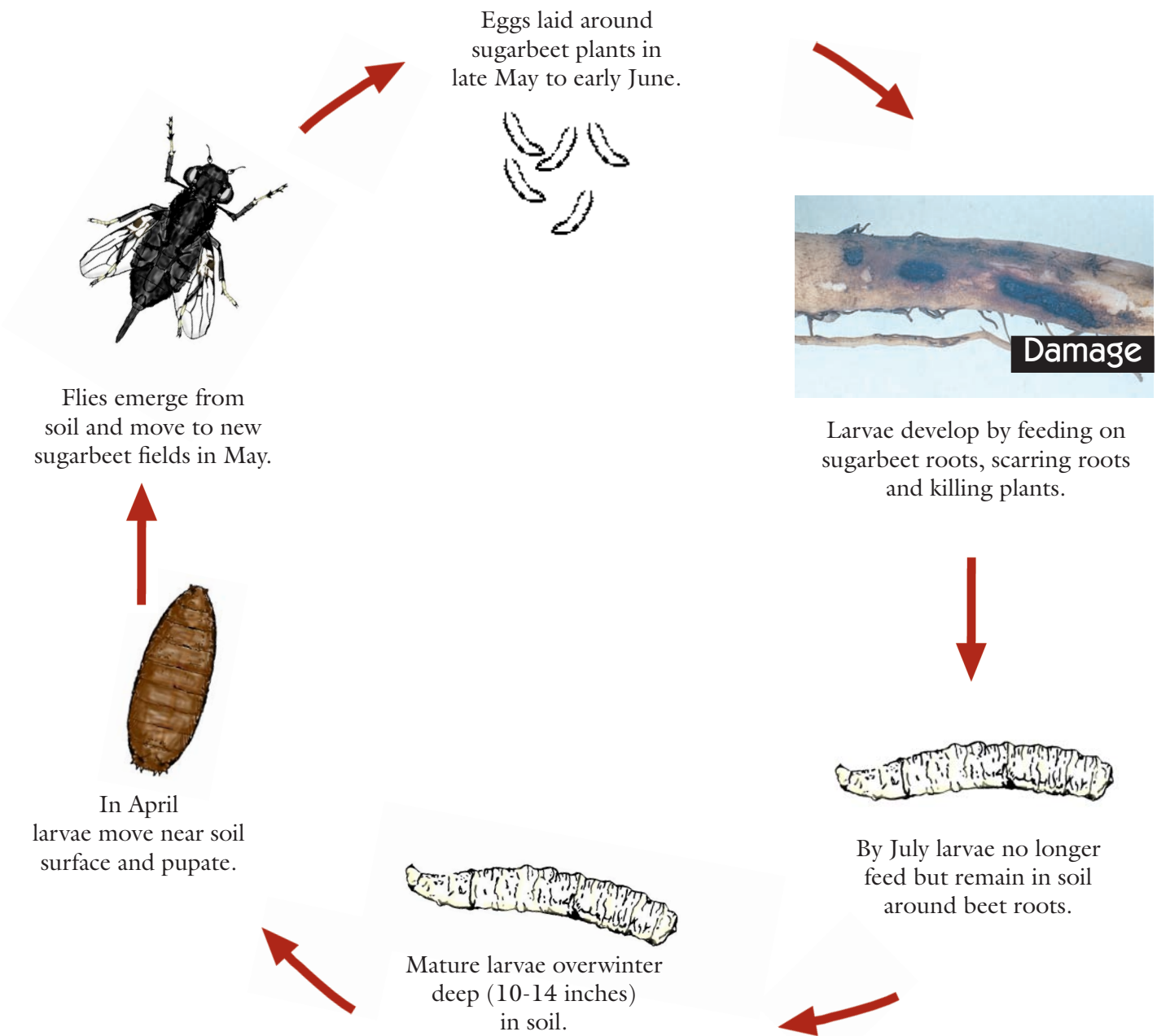


**Figure 9.33**  
Sugarbeet root maggot adult fly on beet leaf.



**Figure 9.34**

Lifecycle of the sugarbeet root maggot.



Sugarbeet Root Maggot Pest Scouting Calendar for Sugarbeets

Sugarbeet Root Maggot	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.-Feb.
Larvae									
Adults									
Eggs									
Peak damage									
Treatment period									



**Figure 9.35**

Sugarbeet root maggot (L-R) eggs, larva, pupa, female adult, male adult. (Courtesy of Robert Dregseth of North Dakota State University.)

The eggs are elongate, slightly curved and white (*Figure 9.35*). The larvae are white, legless maggots that grow to about  $1/3$  to  $1/2$  inch in length. The head end is tapered to a point and the rear end is blunt. The pupae are tan to brown, elongate capsules about  $5/16$  inch long.

Sugarbeet root maggots overwinter as full-grown larvae about 10 to 14 inches deep in the soil. As temperatures begin to warm in the spring, the larvae move up close to the soil surface and pupate. In western Nebraska, sugarbeet root maggots pupate in April, and flies begin to emerge in early May. The flies move from last year's sugarbeet fields to the current fields soon after emergence. The flies are not strong fliers, and movement is generally limited to localized flights to adjacent fields. Fly activity in sugarbeet fields increases under warm and calm conditions. During cool or windy periods the flies remain in sheltered areas along field margins (e.g. weedy, grassy areas or tree rows). Peak emergence and fly activity occur in late May or early June. The females lay eggs in the upper  $1/4$  to  $1/2$  inch of soil at the base of the sugarbeet plants or in the crown area of the beet. Eggs are laid in batches of a few to as many as 40, and a female will lay over 100 during her life. Survival of eggs and early larval stages is greatly reduced in dry soils. The larvae begin to feed on the sugarbeet roots and continue to feed for three to four weeks. By late June to early July, feeding ceases, but the larvae remain in the soil around the sugarbeet roots.

#### *Plant Response and Damage*

Root maggots feed on the surface of the sugarbeet root causing surface scarring (*Figure 9.36*). Deeper scarring and malformed roots may result from heavi-



**Figure 9.36**

Sugarbeet root maggot scarring damage on beet root.

**Figure 9.37**

Sugarbeet root maggot larvae on damaged (cut) sugarbeet root.



**Figure 9.38**

Sugarbeet roots severely damaged by sugarbeet root maggot.



er feeding. Heavy infestations of the sugarbeet root maggot can cause severe stand loss, particularly with small plants, because the maggots feed on and sever the tap root (*Figure 9.37*). Severe damage is obvious because plants become severely wilted or die. If stands are not reduced, losses may still result from reduced plant vigor (*Figure 9.38*). Other stresses, such as hail, can more severely impact sugarbeet damaged by the sugarbeet root maggot because vigorous plants are necessary for recovery.

### *Management*

Cultural practices will not eliminate sugarbeet root maggot problems but can reduce the severity of damage.

Areas where close

rotations of sugarbeet are used will likely have more serious problems because the flies move from the previous year's sugarbeet fields to the current fields. If sugarbeet fields are concentrated in an area, more flies will be emerging, and damage potential will be increased. Conversely, in areas where there were no sugarbeet fields the previous year, the risk of maggot damage is low.

Establishing a vigorous sugarbeet plant as early as possible will also aid in reducing sugarbeet root maggot damage. The larger, more vigorous plants can withstand more damage, and stand reduction will be less likely.

Typically granular insecticides applied at planting have been used to control root maggots. Options have included Counter 20CR and 15G, Lorsban 15G, and Temik 15G. Organophosphate insecticides (Counter, Lorsban) sometimes



have caused phytotoxicity problems when applied at planting (see *Insect Management, Insecticide Application*, page 114). Counter has been shown to be the least phytotoxic of the organophosphates, and placement of the granules behind the planter press-wheel can reduce, but not eliminate the damage. All these products are influenced by environmental conditions. For example, control with planting time applications of Temik 15G can be severely reduced during wet springs because of its water solubility, and the chemical may be leached below the zone where control is needed.

Use of Lorsban 4E as a lay-by control of sugarbeet root maggots provides flexibility in managing several problems associated with the granular materials; however, proper timing is critical, and applications must be based on fly population information obtained from sticky-trap sampling. Phytotoxicity (leaf curling) can result from Lorsban 4E applications. Injury will be minimal unless the plant is stressed by other factors (e.g. hot and sunny conditions, wind damage, herbicide injury). Because of its phytotoxicity potential, Lorsban 4E should not be applied with Betamix or Progress, at either regular rates or micro-rates. To minimize damage potential, Lorsban 4E should not be applied within two days before or within one day after a Betamix or Progress application.

In areas of very serious maggot damage potential, layby treatments have been used in addition to planting time applications. In years when rainfall between planting and peak fly activity has been sufficient, planting time organophosphate treatments should provide good control and supplemental lay-by treatments should not be needed. However, if very little rain has fallen between planting and peak fly activity, a supplemental lay-by treatment may be needed to provide additional control. Lay-by treatments also may be beneficial in years when peak fly activity occurs later than normal in the season (e.g. mid June in western Nebraska) because planting time treatment would no longer be effective.

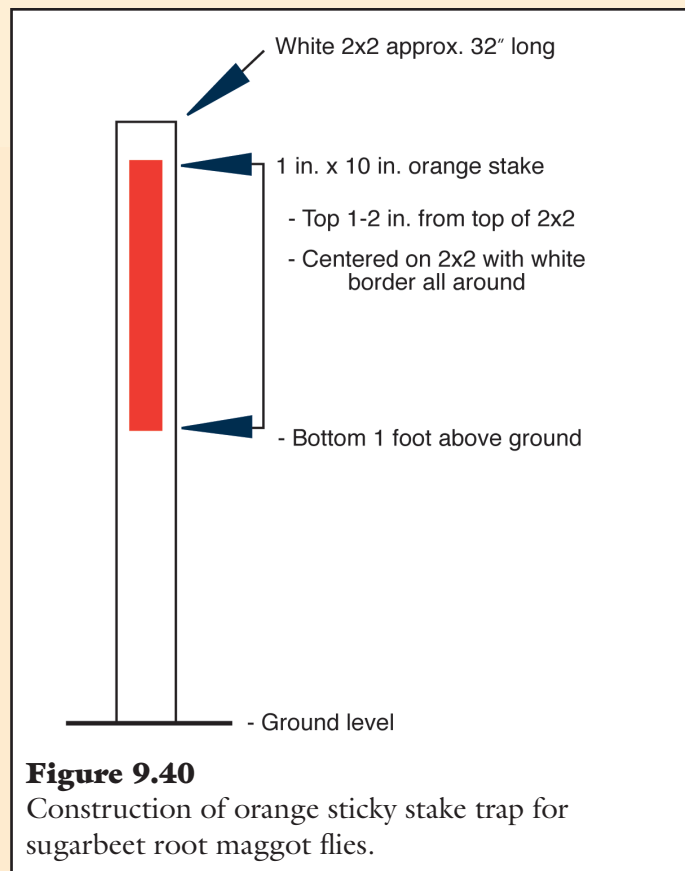
Once maggot damage begins to appear in the field, effective options to correct the situation are limited. Irrigation can help reduce damage once the maggots are feeding on the sugarbeet. Moist soil conditions will cause the maggots to move higher on the roots and be less likely to sever the tap root. Irrigation also will reduce water stress and the potential for stand loss. A lay-by nitrogen application may stimulate beet growth to help plants recover from damage. The value of this practice may be questionable if adequate fertility has already been applied. After damage has been observed, Temik 15G, because of its high water solubility, can be knifed in on the water side of the row (furrow irrigation) or banded over the top of the row (sprinkler irrigation) and watered into the soil. Very little control will be obtained if watering (or rainfall) does not occur after chemical application or if the insecticide is applied too late. Other insecticides are not water soluble enough to provide control of established maggots even with watering.

# Sugarbeet Root Maggot Trap

## Construction and Placement

### Trap Construction

1. Traps are made from a 2 inch x 2 inch wooden board that has been painted white and a garden stake, approximately 1 inch x 10 inches, that has been painted a bright, but not fluorescent, orange. (Similar plastic orange stakes precoated with adhesive are available commercially.) Attach the garden stake to the 2x2 about 1 inch to 2 inches from the top of the stake so that a white border surrounds the stake. When the 2x2 is driven into the ground, the bottom of the orange stake should be about 1 foot above the soil surface.
2. Tangletrap, an insect trap adhesive, is placed only on the orange stake in a thin layer. Adding too much adhesive will lead to a messy trap, but be sure to add enough to be able to catch the flies. Tangletrap can be obtained from one of several pest management suppliers; see NebFact NF93-141, *Sources of Pest Management Supplies*, University of Nebraska Cooperative Extension.



### Trap Placement in the Field

1. Traps should be placed in the field by the first week of May (in western Nebraska) and monitored into mid to late June or until fly populations have declined.
2. Four traps should be placed around the perimeter of the current year's sugarbeet field.
  - Traps can be placed at the edge of the field in a fence-row or next to a ditch just out of the range of the cultivator so they will not be knocked over during field operations.
  - Two traps should face north or west and two should face south or east. This arrangement will usually allow two traps to escape being coated with dirt after a strong northwest or southeast wind.
  - The orange stake on the trap should face the sugarbeet field or be at a 90° angle to the field.
  - Weeds or grass growing around the trap should be cut or pulled for at least a two-foot radius to maintain trap visibility.
3. Traps should be monitored at least two to three times a week.
  - Count or record the number of sugarbeet root maggot flies for each trap.
  - The sticky traps do collect flies other than sugarbeet root maggot flies, so correct identification is essential for an accurate count (*Figure 9.41*). See the earlier description of the flies.
  - Flies should be cleaned off the trap and fresh adhesive applied. If adhesive remains clean and sticky, dead flies can be picked off and sticky material left for the next trap check. Take care to keep the adhesive material on the trap sticky. Dirt and other insects, if numerous, can limit the fly catch because of limited or no sticky surface to catch the flies. The most common problems in reduced stickiness results from dust storms or high insect numbers, particularly flies near feedlots.
4. Risk levels for adjacent fields or fields in close proximity will be similar. A single set of traps can be used to monitor the risk in these fields.



### Sampling Adult Populations

Sugarbeet growers in areas where the sugarbeet root maggot is a problem can improve their management by using the orange sticky-stake trapping method (*see page 110*) originally developed in Idaho (Blickenstaff trap). This method can be used to monitor the development of fly populations in and around sugarbeet fields in May and June. In many areas of the region root maggot populations fluctuate. Without population information it is impossible to make an informed decision on the need to treat or how to treat for sugarbeet root maggot. Growers in these areas may be caught off guard when a problem eventually develops or they may waste dollars on treatments that aren't needed. In areas where the root maggot is continuously a serious problem, growers have had serious control problems even with the use of planting-time insecticides. The sticky-stake method (*Figure 9.39*) can be used to determine both the need and the proper timing for a supplemental lay-by treatment that will improve control in these serious situations.



**Figure 9.39**  
Sugarbeet root maggot  
orange sticky stake.

The orange sticky-stake trapping method should be deployed early — the first week of May in western Nebraska — to catch the first fly activity of the season. As the season progresses, the size and duration of the fly population can be determined. Information gained from the use of the sticky-stake fly traps can be used to:

1. Determine the current population level in the field and assess the need for insecticide treatments in subsequent years in adjacent fields. Anyone just learning to use the trapping system should use this option. This allows one to get used to the trapping method and gain insight into the fly population level in your area. The presence or lack of dying beets in the field is not an accurate way to determine if flies are a problem. Monitoring the flies can give a reasonable idea as to the damage potential of the maggots in the area.
2. Determine the damage potential for the current root maggot fly populations. Decisions can then be made on the need for lay-by insecticide treatments and the proper timing of these treatments.

### Using Trap Data in Decision-making

1. Record the number of sugarbeet root maggot flies caught on each trap at each observation.
2. Keep an accumulated total for the traps and determine the field average. The accumulated total is determined by adding the number of flies in a trap since the beginning of the season (number of flies per trap).
3. Decisions can be made concerning the use of an insecticide the *next year* based on the average accumulated fly trap catch for the field.
  - a. *If fly populations are very low* with a total accumulated catch per trap of less than 20 flies for the season, a planting time treatment would likely not be needed; however, the fly population will need to be monitored



the next year to determine if it's building and may pose a threat.

- b. *If fly populations are moderate* with a total accumulated catch per trap of 20-80 flies for the season, the damage potential is moderate and one of several treatment options can be used.
    - Apply a planting time soil insecticide to control the root maggot problem. This can be effective, however many factors influence the insecticide in the weeks between planting and when it is needed. Also, because of the phytotoxicity risk from some products, this option should be used only when there is demonstrated risk from root maggots (i.e. previous damage or high fly populations).
    - Use an early lay-by application of a granular soil insecticide for root maggot control. This option reduces the risk from phytotoxicity, but lack of water (precipitation) to move the chemical into the soil may reduce control. This would be the best option if overhead sprinkler irrigation is possible.
    - Forego an at-plant insecticide and rely on a liquid lay-by application based on the trapping threshold to provide control of the maggot population. This option works well, but fly monitoring and proper timing are critical. (See No. 4 below.)
  - c. *If fly populations are very high (more than 80 per trap)*, a planting time soil insecticide may be the best option to begin control of root maggots. If the fly populations in a field treated at planting are very high during the season, a lay-by application of Lorsban 4E can provide supplemental control to the planting time application. This has been shown to be quite effective in situations of severe root maggot damage.
4. Decisions can be made concerning lay-by treatments and timing for the *current year*.
    - a. If the total accumulated catch per trap never exceeds 40 flies, the damage potential is low.
    - b. If the total accumulated catch per trap exceeds 40 flies by peak fly activity (before trap catches begins to drop off), a significant potential for damage exists and if no planting time insecticide was used, some type of rescue treatment would be in order. Peak fly activity usually occurs between May 20 and June 10 (in Nebraska). **Lay-by treatments should be timed according to the timing of significant fly activity.** Rescue treatments applied after major larval activity has begun are too late and will be of little use. When using liquid lay-by treatments, timing is critical. **They should be applied when the threshold of 40 flies per trap is reached.** This may occur before the actual peak fly activity period is noted on the sticky traps. If the period of high fly activity is extended 7-10 days after the first treatment, a second liquid insecticide treatment may be needed to control the later population.

The best decisions for managing the sugarbeet root maggot can only be made when you know what the potential for damage is in your fields. That potential can only be obtained from trapping the maggot flies with the orange sticky stake method.

## White Grub

White grub problems in sugarbeet are uncommon. Treatment for this insect would not likely be economic unless planting into a high risk situation (i.e. following sod or grass).

### Identification and Life Cycle

White grubs are C-shaped insects (*Figures 9.42 and 9.43*) ranging in length from 1/2 to 1 1/2 inches. These larvae live in soil for extended periods of one to three years. The adults are active in early summer when they emerge from the soil, mate and lay their eggs in grass or pasture areas.

### Plant Damage and Response

White grub problems are mostly limited to crops, especially row-crops, planted after sod or other grasses; however, they also may build up in cropland where grass weed problems have been severe. They feed on the sugarbeet root and can cause problems early in the year when plant damage can lead to stand loss. Damaged plants at this time will wilt and die (*Figure 9.42*). Also, late season grub feeding can result in severely pitted and damaged sugarbeet (*Figure 9.43*).

### Management

Sugarbeet and other row crops should not be grown following sod. If grub problems are expected, a soil applied insecticide may provide some degree of control; however, severe white grub infestations are difficult to control.



**Figure 9.42**  
Early season white grub damage to sugarbeet.



**Figure 9.43**  
Late season white grub damage to sugarbeet.

## Insecticide Application

### Granular Insecticides

The granular insecticides available for use in sugarbeet are used to control soil insects. Two classes of soil insecticides (carbamates and organophosphates) are currently registered for control of sugarbeet insects. Studies have shown

**Figure 9.44a and 9.44b**

Insecticide phytotoxicity to sugarbeet: (top) undamaged; (bottom) stunted and damaged.



the potential for planting time applications of organophosphates to cause phytotoxicity on sugarbeet both alone and in combination with pre-plant herbicides. In some situations the damage from the combination of insecticides and herbicides will be additive and cause substantial crop damage. Sugarbeet damage symptoms from insecticides and herbicides are similar. Young sugarbeet that have been damaged by insecticides show curled or distorted cotyledons that may become unusually thickened (*Figures 9.44a-9.44b*). These beets are very susceptible to further stresses and can sometimes stop growing and die. Reduced stands and stunting are the most visible symptoms of phytotoxicity problems (*Figure 9.45*), but this often carries through to reduced yields as well. The carbamate insecticides have been shown to be less damaging than the organophosphates which can cause severe stand losses and reduced vigor even when applied at labeled rates and placements. Proper placement of these insecticides at planting can reduce the potential for phytotoxicity damage.

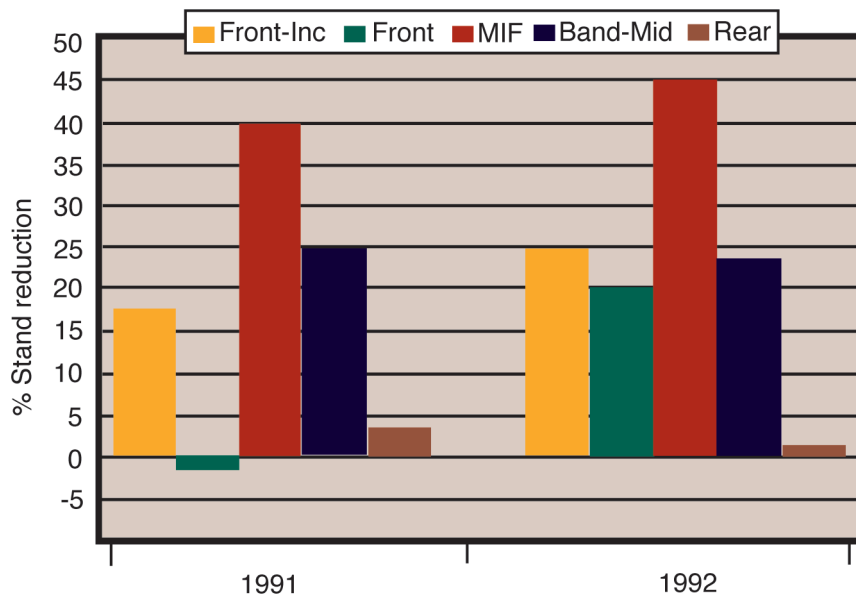
Studies have shown that insecticide placement does have a large influence on phytotoxicity (*Figure 9.46*). Insecticides placed as a modified in-furrow application resulted in the greatest damage to the sugarbeet. Insecticides applied behind the planter unit but ahead of the press wheel resulted in the next most damage, and even application to the front of the planter unit resulted in substantial damage. The least damage was from placement behind the press wheel, but even placement here did not eliminate the problem. It is clear that this phytotoxicity is modified by many factors, including presence of herbicides and other stresses on the sugarbeet. In years when sugarbeet emerge with little stress, phytotoxicity will likely be minimal, but the greater the environmental and chemical stresses on the plant, the greater the potential for phytotoxicity. The phytotoxic response of these chemicals also seems to be influenced sub-

*Insecticide placement can have a major influence on phytotoxicity.*





**Figure 9.45**  
Insecticide phytotoxicity to sugarbeet: left, damaged; right, undamaged.



**Figure 9.46**  
Insecticide phytotoxicity damage relationship for various insecticide placements on sugarbeet.  
Front-Inc = in front of planter unit and incorporated.  
Front = in front of planter unit.  
MIF = modified in-furrow.  
Band = in front of press wheel.  
Rear = behind press wheel.

stantially by the soil type and/or organic matter. In regions with higher organic matter, the response of sugarbeet to these chemicals is not nearly as significant.

### Foliar Insecticides

Some foliar insecticides also can result in phytotoxic effects on sugarbeet. The application of Lorsban 4E can result in leaf curling and stunting (*Figure 9.47*). This damage has been shown to have an impact on subsequent yield in some situations. Damage by Lorsban 4E is influenced by environmental conditions with damage being more severe when the chemical is applied under hot, sunny conditions particularly if this period follows several cloudy days. Damage is also made worse when applications of herbicides (particularly Betamix and Progress) precede or follow Lorsban application by less than one to two days. Applying Lorsban during the cooler parts of the day and using lower rates and/

**Figure 9.47**  
Phytotoxicity  
damage to sugarbeet from  
foliar Lorsban application.



or greater volumes of carrier reduces the potential for damage.

#### **Seed Treatments**

Seed treatments can be used to control seed and seedling insects; however, the effectiveness of some of the standard planter box applied seed treatments may be questionable because of the

inability of getting an adequate and uniform rate applied to the seed. The use of newer commercial seed treatments, such as Gaucho, solves most of the application problems associated with seed treatments. Because the treatment is by commercial applicators and applied directly to the seed pellet, the problems with adherence and rate variability are solved. There is a trend toward using seed treatments to deliver insecticides. If more of these products become available, it will be important to evaluate them on the basis of their effectiveness in controlling the target insects and potential for crop injury.

*Integrate various pest management strategies to avoid the development of insecticide resistance.*

## **Managing Insecticide Resistance**

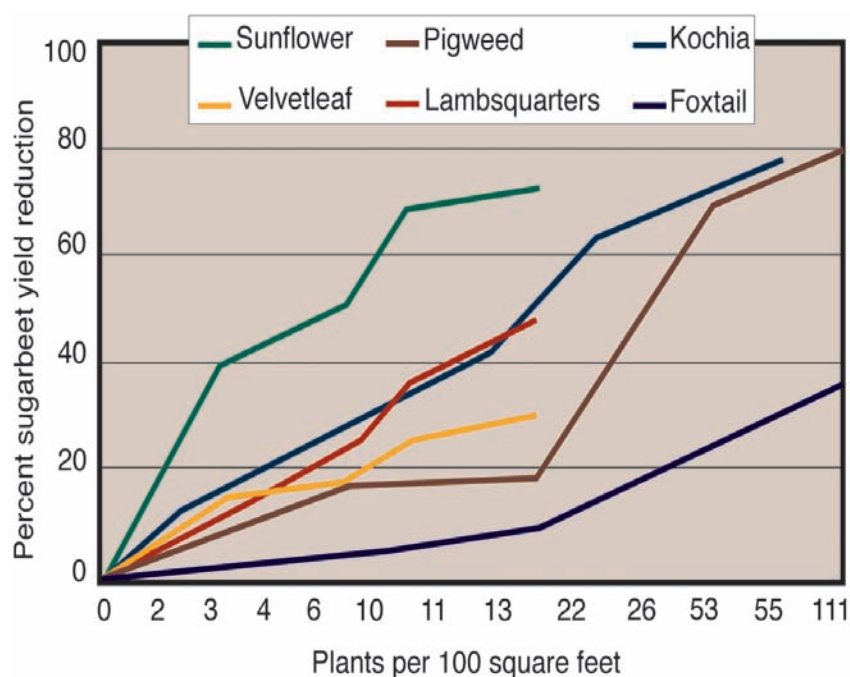
Repeated exposure of an insect population to the same insecticide or even the same class of insecticides, over several generations, can result in an insecticide-resistant population. These repeated applications provide enough selective pressure on the population to allow only individuals that are highly resistant to the chemical to survive. The result is an insect population that cannot be controlled with that insecticide or perhaps even other related insecticides. Because of the limited number of insecticide control options for some sugarbeet insects, loss of control for an insecticide will be particularly problematic. It is important to consider the potential for insecticide resistance in developing insect management strategies. Consider the following points to reduce the potential for developing insecticide resistance.

- Use integrated pest management practices to reduce potential for pest problems whenever possible.
- Use insecticides only when necessary, scout fields for insect presence and treat only when economic thresholds are reached.
- If possible, rotate insecticides between insecticide classes to reduce selective pressure on the insect population.
- Scout for the development of insecticide resistance by evaluating the effectiveness of treatments.

By Robert G. Wilson, Stephen D. Miller, and Scott J. Nissen

## Weed Competition

Weeds have a tremendous impact on sugarbeet root yield, especially those that become taller than the crop. They will cause greater yield loss than weeds that do not overtop the crop canopy. For example, common sunflower, kochia, common lambsquarters, velvetleaf, redroot pigweed and green foxtail at densities of six plants per 100 square feet can reduce sugarbeet root yields by 51 percent, 30 percent, 26 percent, 16 percent, 16 percent and 1 percent respectively (*Figure 10.1*). Time of emergence has a significant impact on competitive ability — weeds emerging with the crop cause greater yield losses than weeds emerging after the crop. For example, redroot pigweed at a density of three plants per 3 foot of row caused a 44 percent sugarbeet yield loss at one location, while the same density at a second location caused a 1 percent yield loss. The more competitive redroot pigweed emerged five days before sugarbeet with a May 10 planting date while the less competitive weed emerged seven days after sugarbeet with an April 27 planting date. The first three weeks after planting are considered critical for weed removal. To prevent crop losses, sugarbeet need to be kept weed-free for approximately eight weeks after planting (*Figure 10.2*). After this period the sugarbeet canopy should be competitive enough to suppress newly emerging weeds. If crop stands are poor or the crop is under stress from pests or lack of fertility, sugarbeet may not suppress late emerging weeds and additional weed control measures may be necessary.



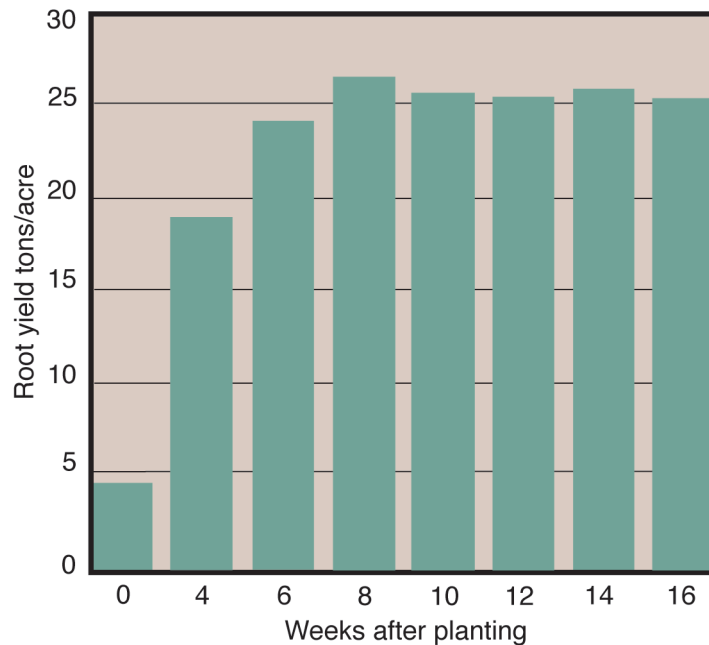
**Figure 10.1**

Influence of various weeds on sugarbeet root yield.



**Figure 10.2**

Influence of various time periods of weed-free maintenance on sugarbeet root yield.



## Recommended Publications on Weed Management

Several universities in the High Plains sugarbeet production region have published excellent guides for herbicide use in sugarbeets. They include:

**Guide for Weed Management in Nebraska**, EC130, available from UNL Extension Publications, Box 830918, University of Nebraska, Lincoln, NE 68583-0918; Phone: 402-472-3023. Cost is \$5, plus shipping and handling.

**The Montana, Utah and Wyoming Weed Management Handbook**, Publication No. B442, available from the University of Wyoming Resource Center, Box 3313, Laramie, WY 82071; Phone: 307-766-2115. Cost is \$15, plus shipping and handling.

**Colorado Weed Management Guide**, XCM205, available from Cooperative Extension Resource Center, 115 General Services Building, Colorado State University, Fort Collins, CO 80523-4061; Phone: 877-692-9358; cost is \$10, plus shipping and handling.

## Planning a Weed Management Program

Several factors should be considered when planning a weed management program. Factors such as weed species, cover crop, preplant tillage, crop rotation, crop cultivar, row spacing, fertility program, cultivation, and herbicides all need to be integrated to develop an effective weed control strategy.

Accurate weed identification should be the first step in any weed management program and is important for effective and economical decisions. Many weeds look similar in the seedling stage; however, their susceptibility to control measures could be quite different. For example, wild buckwheat and field bindweed often are confused early in the growing season. Field bindweed is a perennial, requiring a different control program than wild buckwheat, an annual. Hairy nightshade, common lambsquarters and redroot pigweed are often confused in the cotyledon growth stage, but proper identification is important in selecting appropriate postemergence herbicide treatments. To aid in proper seedling identification, a series of 23 images of common weed seedlings affecting sugarbeet in this region are presented in *Figures 3 to 25, pages 120 to 121*.

Mapping weed infestations in a field can aid weed management decisions. Perennial weeds such as Canada thistle and quackgrass usually occur in patches. Scattered patches and individual weeds can be spot-treated with a herbicide, rogued or cultivated.

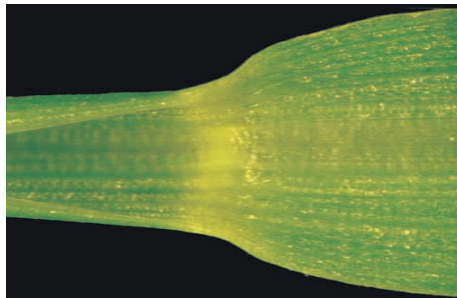
Tillage associated with seedbed preparations has a major impact on weed spectrum and population. Non-inversion tillage (i.e. chisel plowing) methods leave a greater proportion of weed seed near the soil surface than do inversion tillage (i.e. moldboard plowing) methods. The increased proportion of weed seed left near the soil surface after chisel plowing increases the potential for weed germination and establishment. Weed seed response to burial and exposure to light varies with the species. Spring tillage seems to stimulate certain seed to break dormancy and germinate. This factor can be integrated into a weed management program. Sugarbeet fields that are moldboard plowed or tilled and bedded in the fall have an advantage over spring tillage. Fall tillage may stimulate germination of certain weed seeds which are then killed by freezing temperatures. Because spring tillage is reduced, weed populations will be lower in fall-tilled areas compared to spring-tilled areas. A similar trend of reduced weed emergence has been observed when winter wheat or rye cover crops are planted in the fall and killed the next spring before sugarbeets emerge.

Herbicides can be applied before planting and crop emergence to control weeds as they germinate and emerge with the crop. Performance of both RoNeet and Nortron is enhanced with incorporation after application. The decision to use a planting time herbicide depends on expected weed problems and crop injury. Information presented in *Table 10.1* details the weed control which can be expected from common sugarbeet herbicides. RoNeet and Nortron may

# Weed Seedlings Common to Sugarbeet

**Figure 10.3**

Barnyardgrass



**Figure 10.7**

Common lambsquarters



**Figure 10.11**

Hairy nightshade



**Figure 10.4**

Black nightshade



**Figure 10.8**

Common sunflower



**Figure 10.12**

Jimsonweed



**Figure 10.5**

Canada thistle



**Figure 10.9**

Giant ragweed



**Figure 10.13**

Kochia



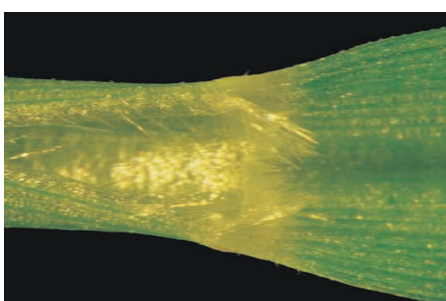
**Figure 10.6**

Common cocklebur



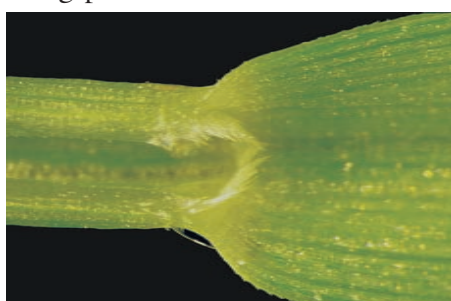
**Figure 10.10**

Green foxtail



**Figure 10.14**

Longspine sandbur





**Figure 10.15**  
Puncture vine



**Figure 10.19**  
Toothed spurge



**Figure 10.23**  
Wild oat



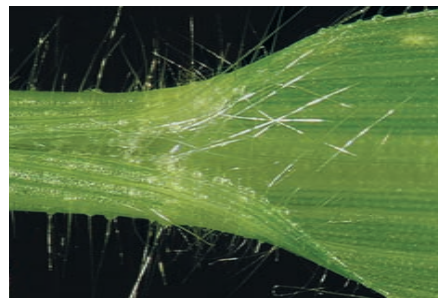
**Figure 10.16**  
Redroot pigweed



**Figure 10.20**  
Velvetleaf



**Figure 10.24**  
Wild proso millet



**Figure 10.17**  
Redstem filaree



**Figure 10.21**  
Venice mallow



**Figure 10.25**  
Yellow foxtail



**Figure 10.18**  
Russian thistle



**Figure 10.22**  
Wild buckwheat



(Source: S.J. Nissen and D.E. Kazarian. 2000. *Common Weed Seedlings of the Central High Plains*. Department of Bioagricultural Science and Pest Management, Colorado State University, Fort Collins, Colorado 80523.)

**Table 10.1**

Herbicides used for control of common broadleaf weeds.

Broadleaf weed control <sup>2</sup>											
Herbicides	Time of application <sup>1</sup>	Canada thistle	Cocklebur	Kochia	Lambsquarters	Hairy nightshade	Pigweed	Russian thistle	Sunflower	Velvetleaf	Wild buckwheat
Nortron	(PPI)	1	5	6	6	9	8	6	4	1	7
RoNeet	(PPI)	1	4	3	8	6	7	4	2	4	6
Betanex	(Post)	2	2	4	7	7	9	5	1	2	5
Betamix	(Post)	2	2	4	8	8	8	5	1	2	5
Progress	(Post)	2	2	5	8	8	9	5	2	2	5
Stinger	(Post)	8	9	3	4	4	1	4	9	3	8
Upbeet	(Post)	2	6	9	5	5	6	5	5	7	7
Roundup	(Post)	7	9	9	9	8	9	8	9	9	7
Liberty	(Post)	3	9	7	7	8	8	8	7	8	7
Eptam	(Layby)	1	3	3	7	8	7	4	3	5	6
Treflan	(Layby)	1	3	8	7	6	8	6	2	3	5
Common Tank Mixes											
Betamix + Upbeet	(Post)	2	6	9	9	8	9	5	6	7	7
Progress + Upbeet	(Post)	2	6	9	9	8	9	6	6	8	7
Betamix + Stinger	(Post)	8	9	5	9	9	8	5	9	3	9
Progress + Stinger	(Post)	8	9	6	9	9	9	6	9	3	9
Betamix + Upbeet + Stinger	(Post)	8	9	9	9	9	9	7	9	7	9
Progress + Upbeet + Stinger	(Post)	8	9	9	9	9	9	7	9	8	9
Micro Rate											
Betamix + Upbeet + Stinger + methylated seed oil	(Post)	8	8	9	8	9	9	7	9	7	9

<sup>1</sup>Time of application; preplant incorporated (PPI), at least two postemergence applications (Post), and applications made postemergence to sugarbeet in the six-leaf growth stage (Layby).

<sup>2</sup>Numbers within tables are based on ratings of percent control; 0 = no control and 9 = 90% to 95% control.

**Table 10.2**

Herbicides used for control of common grasses.

Herbicides	Time of application <sup>1</sup>	Grass control <sup>2</sup>							Crop safety	
		Barnyardgrass	Foxtail	Sandbur	Quackgrass	Volunteer grain	Wild oats	Wild proso millet	Crop tolerance <sup>3</sup>	Carryover <sup>4</sup>
Nortron	(PPI)	5	8	6	3	5	5	5	G	12
RoNeet	(PPI)	5	9	7	3	6	6	7	G	2
Assure II	(Post)	9	9	9	8	9	9	9	E	4
Betanex	(Post)	4	6	6	3	3	3	5	G	1
Betamix	(Post)	4	6	6	3	3	3	5	G	1
Liberty	(Post)	7	8	7	7	7	7	8	E	0
Poast	(Post)	6	9	7	8	7	7	9	E	0
Progress	(Post)	4	7	7	3	3	3	5	F	12
Select	(Post)	9	9	9	8	9	8	9	E	0
Stinger	(Post)	1	1	1	1	1	1	1	G	12
Roundup	(Post)	9	9	9	9	9	9	9	E	0
Upbeet	(Post)	4	5	6	3	3	3	5	G	0
Eptam	(Layby)	6	9	9	6	7	7	8	E	1
Treflan	(Layby)	9	9	7	6	7	7	7	G	12
Common Tank Mixes										
Betamix + Upbeet	(Post)	4	7	6	3	3	3	5	G	1
Progress + Upbeet	(Post)	4	7	6	3	3	3	5	F	1
Betamix + Poast	(Post)	6	8	7	7	6	6	8	G	1
Betamix + Select	(Post)	8	8	8	7	8	7	8	G	1
Betamix + Stinger	(Post)	4	6	6	3	3	3	5	G	12
Progress + Stinger	(Post)	4	6	6	3	3	3	5	F	12
Betamix + Upbeet + Stinger	(Post)	4	7	6	3	3	3	5	F	12
Progress + Upbeet + Stinger	(Post)	4	7	6	3	3	3	5	F	12
Micro Rate										
Betamix + Upbeet + Stinger + methylated seed oil	(Post)	4	7	6	3	3	3	5	G	12
Betamix + Upbeet + Stinger + Select + methylated seed oil	(Post)	7	8	7	7	7	7	8	G	12

<sup>1</sup>Time of application; preplant incorporated (PPI), at least two postemergence applications (Post), and applications made postemergence to sugarbeet in the 6-leaf growth stage (Layby).

<sup>2</sup>Numbers within tables are based on ratings of percent control; 0 = no control and 9 = 90% to 95% control.




<sup>3</sup>Crop tolerance; excellent (E), good (G) and fair (F).

<sup>4</sup>Number of months after application for planting to a non-labeled crop.



**Table 10.3**

Common sugarbeet herbicide effects on weeds and sugarbeet injury symptoms.

Herbicide/chemical class	Effect on weeds	Sugarbeet and weed injury symptoms
<b>Preplant, applied postemergence to weeds before crop emergence</b>		
Roundup Ultra Chemical class: Unclassified	Inhibition of amino acid synthesis Inhibition of EPSP synthase	Plant foliage, especially new growth will turn yellow then brown (see Figure 10.26).
		<b>Figure 10.26</b> Amino acid inhibitor
<b>Preplant incorporated, preemergence</b>		
Nortron Chemical class: Unclassified	Inhibition of seedling growth; weeds do not emerge from soil	General stunting, crinkled, fused leaves (see Figure 10.27 and Figure 10.28).
RoNeet Chemical class: Carbamothioates	Inhibition of seedling growth Inhibition of fatty acid biosynthesis; weeds do not emerge from soil	General stunting, crinkled leaves, shortened leaf mid-vein producing drawstring effect (see Figure 10.27 and 10.28).
		<b>Figure 10.27</b> Root and shoot inhibitor
		<b>Figure 10.28</b> Root and shoot inhibitor
<b>Postemergence</b>		
Assure II Chemical class: Aryloxyphenoxypropionates	Inhibition of fatty acid production in grass species only	No effect on sugarbeet
Poast, Select Chemical class: Cyclohexanediones	Yellowing (chlorosis), browning (necrosis) of leaves emerging from whorl Symptoms develop slowly (7-14 days)	

Herbicide/chemical class	Effect on weeds	Sugarbeet and weed injury symptoms
<b>Postemergence</b>		

Upbeet Chemical class: Sulfonylureas	Inhibition of production of amino acids stops plant growth by inhibiting protein synthesis	Minor stunting Yellow (chlorosis) appearance to leaves ( <i>see Figure 10.29</i> ).
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**Figure 10.29**  
Amino acid inhibitor

Roundup Ultra Chemical class: Unclassified	Inhibition of production of amino acids	Plant foliage especially new growth will turn yellow ( <i>see Figure 10.26</i> ).
Liberty Chemical class: Unclassified	Inhibition of EPSP synthase Inhibition of glutamine synthase	
Stinger Chemical class: Carboxylic acids	Disrupt hormone balance and protein synthesis	Stem elongation, twisting, leaf cupping ( <i>see Figure 10.30</i> ).



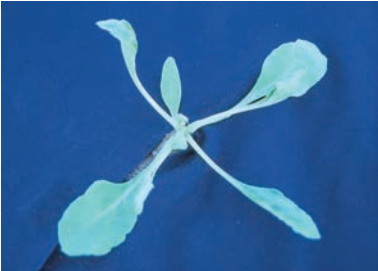





**Figure 10.30**  
Growth regulator

Betanex, Betamix Chemical class: Phenylcarbamates	Inhibition of photosynthesis	Leaves turning yellow or bronze, affected areas turn brown and die, injury confined to foliage at time of application, newly emerging leaves unaffected. ( <i>see Figure 10.35</i> ).
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<b>Postemergence, layby</b>		
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Dual II Magnum, Outlook Chemical class: Chloroacetimides	Inhibition of seedling growth Inhibition of shoots	General stunting, leaf crinkling, root pruning
Eptam Chemical class: Carbamothioates	Inhibition of lipid synthesis	
Treflan Chemical class: Dinitroanilines	Inhibition of microtubule assembly Weeds do not emerge from soil	

**Table 10.4**  
 Sugarbeet injury symptoms associated with other crop herbicides.

Herbicide mode of action: product names	Sugarbeet injury symptoms
<b>Growth regulators</b> 2,4-D, Banvel, Clarity, Tordon Chemical classes: Phenoxy acetic acid, Benzoic acid and Picolinic acid	<b>Drift and carryover</b> Stem twisting (epinasty) Leaf cupping, crinkling, stem elongation
 <b>Figure 10.31</b> Growth regulator	 <b>Figure 10.32</b> Growth regulator
<b>Amino acid inhibitors</b> Pursuit, Raptor, Amber, Ally, Accent, Harmony, Maverick Chemical classes: Imidazolinones, Sulfonylureas	<b>Drift and carryover</b> Stunting, yellowing of new growth then brown
 <b>Figure 10.33</b> Amino acid inhibitor	 <b>Figure 10.34</b> Amino acid inhibitor
<b>Photosynthesis inhibitors</b> Atrazine, Bladex, Buctril, Sencor, Tough, Velpar Chemical classes: Triazines, Triazinones, Nitriles, Phenylpyridazine	<b>Drift and carryover</b> Does not prevent germination or emergence of crop, initial yellowing of leaf margin, affects older leaves more than younger leaves, injured tissue turns brown and dies
 <b>Figure 10.35</b> Photosynthesis inhibitor	 <b>Figure 10.36</b> Photosynthesis inhibitor



Herbicide mode of action: product names		Sugarbeet injury symptoms	
Cell membrane disruptors		Drift	
Gramoxone, Blazer, Goal, Aim Chemical classes: Diphenylethers, Aryl triazinone, Bipyridyliums		Affected areas turn yellow, then brown and and eventually die, sometimes water soaked or reddish colored spotting on leaves	
	<b>Figure 10.37</b> Cell membrane disruptor		<b>Figure 10.38</b> Cell membrane disruptor
Pigment inhibitors		Drift and carryover	
Balance, Command Chemical classes: Isoxazole, Isoxazolidinone		Plants turn white, often becoming translucent at the tips	
	<b>Figure 10.39</b> Pigment inhibitor		<b>Figure 10.40</b> Pigment inhibitor

**Figure 10.41**

Crop injury from a herbicide belonging to the root and shoot inhibitor chemical family.



injure the crop and cause early season stunting (*Figure 10.41*). Crop injury may vary with the sugarbeet variety, degree of incorporation, amount of rainfall after application, and speed of crop emergence. Crop injury can be reduced by lowering the herbicide rate.

Field scouting immediately after the crop begins to emerge is important to identify

weeds and provide the information necessary to choose a postemergence herbicide program that matches the weed spectrum. Several herbicides can be applied postemergence in sugarbeet (*Table 10.1*). Each herbicide selectively controls specific weeds. For broadleaf weeds, Betamix or Progress are considered foundation treatments and can be tank mixed with other herbicides depending on the weed spectrum. As an example, if common sunflower, common cocklebur or wild buckwheat were present, Stinger could be added to Betamix or Progress to improve weed control. If kochia were present, Upbeet could be added to Betamix or Progress to improve the spectrum of control. Consult *Tables 10.1* and *10.2* for more information on herbicide performance. Consult the “Guide for Weed Management in Nebraska”, “The Montana, Utah, and Wyoming Weed Management Handbook”, “Colorado Weed Management Guide” or the herbicide labels for application rates and specific information about individual herbicides.

Start weed control programs early by applying the first postemergence treatment when sugarbeet are in the cotyledon growth stage. Follow the first treatment five to seven days later with a second application. It is critical to use the second application within five to seven days or else weed control may be diminished. If more weeds emerge or weeds haven’t died, follow the second application with a third or fourth treatment. The goal of this early season program is to provide the crop with at least six weeks of growth without weed competition.

Several postemergence herbicides can cause crop injury resulting in stunting. This early season injury can result in moderate yield reductions. Care should be taken to follow label directions and start spraying in late afternoon on days when the temperature may reach 80°F. An alternative approach to Betanex, Betamix and Progress application is to use a reduced rate of these products in combination with Upbeet and Stinger plus methylated seed oil adjuvant. This program has been called micro-rate. Methylated seed oil adjuvant increases herbicide activity on weeds, allowing the herbicide rate to be reduced 75 percent. Micro-rate programs consist of a minimum of three herbicide applications beginning with crop and weed emergence (cotyledon growth stage). Compared to two applications of Betamix plus Upbeet Plus Stinger without methylated seed oil, three micro-rate applications have provided similar to slightly reduced weed control with similar sugarbeet tolerance.

Six weeks after emergence, sugarbeet leaves should be beginning to cover the spaces between plants, suppressing further weed growth. Several cultural practices such as optimum plant arrangement, narrow rows, higher plant populations, proper fertilization and selection of cultivars with good disease tolerance

*Sugarbeet should be kept weed-free for the first eight weeks after planting to prevent crop losses.*

further favor the crop by maximizing shading and hastening canopy closure. Other conditions that favor the crop are timely planting, irrigation for emergence and pest control. If sugarbeet stands are poor and the crop is under stress from diseases or insects, weeds will take advantage of the open canopy and continue to be competitive. Herbicides can be applied layby to help the crop in suppressing late season weed emergence if crop stand and vigor are lacking.

## Herbicide-Tolerant Sugarbeet

With herbicide-tolerant transgenic sugarbeet, a gene has been inserted or changed in the plant, allowing it to tolerate a herbicide that would normally kill it. Two systems were recently developed through gene insertion and provide tolerance to Roundup and Liberty herbicides. Currently, sugarbeet processors are not accepting transgenic sugarbeet varieties. These weed management systems have the potential to be more economical, improve crop safety, control larger weeds, provide greater environmental safety and allow reduced tillage production systems. Potential concerns with these systems are consumer acceptance, seed cost, yield drag with herbicide tolerant sugarbeet varieties and development of weed resistance. Three applications of Liberty beginning when the crop is in the cotyledon to two true-leaf growth stage or two applications of Roundup Ultra beginning when the crop is in the two to four true-leaf growth stage have provided excellent weed control. Deciding whether to use Liberty or Roundup depends on the weed problem, transgenic sugarbeet variety and yield potential.

## Herbicide Resistance

Herbicide resistance occurs from repeated use of a herbicide or herbicides with the same mode of action. Repeated herbicide use eliminates susceptible weeds and allows resistant weeds to increase in the absence of competition from susceptible plants. Genetically diverse weed species may contain a small percentage of plants that are resistant to a particular herbicide mode of action. Repeated exposure of a weed population to a herbicide may result in a rapid buildup of weed resistance to that herbicide mode of action. Resistant weeds may then dominate over time due to this selection pressure.

Risk of selecting a herbicide resistant weed population increases by using residual herbicides that provide near 100 percent weed control. Growers should not rely on one herbicide class in a crop rotation system. Even though crops are rotated, there are many situations where herbicides with the same mode of action can be used in different crops. An example would be Basis applied in corn, Upbeet in sugarbeet and Pursuit in dry bean, even though the herbicides are different, they have a similar mode of action. Plants that have developed herbicide resistance are kochia, pigweed/water hemp, cocklebur, nightshade, sunflower, foxtail and wild oats. Computer models estimate resistance in kochia and other species to occur at 1 resistant plant in 10,000 to 100,000 plants.



*Repeated use of herbicides with the same mode of action eliminates susceptible weeds and allows resistant weeds to develop.*

## Strategies to Minimize Herbicide Resistant Weeds

1. Use herbicides only when necessary.
2. Rotate herbicides with different modes of action in consecutive years.
3. Apply herbicides as tank-mixes or use sequential treatments that contain multiple modes of action.
4. Rotate crops with different life cycles, winter annual crops (winter wheat), perennial crops (alfalfa) and summer annual crops (corn or dry bean).
5. Combine mechanical and chemical weed control practices.
6. Scout fields regularly to identify weeds that escape herbicide treatments.

## Crop Injury from Herbicides

Sugarbeet injury can occur from herbicides applied to the crop for weed control (*Table 10.3*) and from herbicides that can drift or carry over in the soil (*Table 10.4*). *Tables 10.3* and *10.4* review sugarbeet injury symptoms and *Figures 10.26* to *10.41* illustrate herbicide injury symptoms. Ally, Atrazine, Pursuit and Treflan are examples of herbicides that can carry over from the previous crop and injure sugarbeet. Damage from herbicide residues in the spray tank also can occur. Some herbicides used in other crops can remain as a contaminate in the spray tank. If the spray tank is not properly cleaned, the herbicide contaminate can injure sugarbeet.

By Gary D. Franc, Robert M. Harveson, Eric D. Kerr, and Barry J. Jacobsen

Diseases have played an important role in the distribution of the sugarbeet industry in the United States. The first sugarbeet factories were constructed near Grand Island and Norfolk in central and eastern Nebraska in 1890, but in 1909 the sugarbeet industry moved to western Nebraska where crop disease pressure was less intense. Similar trends were evident in other parts of the United States as producers experimented with crop production. By 1930 the general pattern of the domestic sugarbeet industry had been established in areas of the United States where crop diseases could be successfully managed.

During the last century many pathogens have been identified that can affect sugarbeet growth. Some of these pathogens can live from season to season in the soil and others can be transported to the crop by wind currents, irrigation water, and by man. For this chapter, pathogens that cause diseases in sugarbeet were subdivided into six categories: viruses, bacteria, fungi affecting roots, fungi affecting foliage, wilt diseases, and nematodes. This chapter focuses on the disease problems known to occur in the High Plains sugarbeet production region.

## Diseases Caused by Viruses

### Beet Curly Top

**Symptoms:** Leaves of susceptible cultivars are dwarfed, crinkled, and rolled inward and upward (*Figure 11.1*). Veins are roughened on the lower sides of leaves and often produce swellings and spine-like outgrowths. Roots are dwarfed and a proliferation of rootlets results in a condition known as hairy root. Phloem tissue becomes necrotic, cracked, and phloem exudate appears on stems and leaves. Necrotic areas may appear as dark rings in cross-sections of tap roots. If infection is delayed until plants are older, symptoms are mild.

**Causal Agent:** Beet curly top virus is a Geminivirus transmitted by the beet leafhopper, *Circulifer tenellus*. It has an extensive host range that includes more than 300 species in 44 plant families. The virus comprises a complex of different strains that vary in their host range and symptomatology.

**Disease Cycle:** In North America, beet curly top virus is only transmitted by the beet leafhopper, *C. tenellus* (*Figure 9.13*). The leafhopper can acquire the virus during several minutes of feeding on an infected host plant and may transmit the virus for a month or longer. The leafhopper can live on a wide range of host plants and



### Diseases Caused by Viruses

Beet curly top virus  
Beet mosaic virus  
Beet necrotic yellow vein virus (Rhizomania)  
Beet soilborne mosaic virus  
Beet western yellows virus

**Figure 11.1**  
Classical beet curly top symptoms.

is capable of breeding on mustards and Russian thistle. Leafhoppers will move into sugarbeet fields from weed hosts as the hosts desiccate and die in rangeland and other non-irrigated areas (see *Beet Leafhopper*, page 91).

**Management:** Plant resistant varieties adapted to the production area. Cultural practices that delay infection will reduce disease severity. These include early planting and weed management to reduce sources (reservoirs) of the virus and the leafhopper. Leafhopper management practices are based on scouting to determine economic thresholds for treatment.

### Beet Mosaic

(Synonyms: *spinach mosaic*, *sugarbeet mosaic*, *Beta virus 2*)

**Symptoms:** Leaf symptoms include mosaic (irregular patches of various shades of green) and puckering (*Figure 11.2*). Young leaves commonly show vein clearing and chlorotic spotting. These spots may appear as sharply defined chlorotic rings with green centers. Infected plants typically are stunted and severe leaf distortion is relatively uncommon. Yield losses on plants infected when young are less than 10 percent. Beet mosaic virus is of little economic importance even though it is distributed worldwide. Its mottling symptoms are similar to those caused by beet yellow mosaic virus and the chlorotic ring spot symptom is similar to that caused by tomato black ring and tobacco rattle viruses.

**Causal Agent:** Beet mosaic virus is a Potyvirus serologically related to potato virus Y, bean yellow mosaic virus and soybean mosaic virus. The virus is spread by more than 28 species of aphids including the principal vectors *Myzus persicae* and *Aphis fabae* (see *Aphids*, page 90). Aphids acquire and transmit the virus in 6-10 seconds and retain the virus on their stylet for 1-4 hours.

Although beet mosaic virus can be transmitted mechanically, it is primarily disseminated by aphids. It is not transmitted by pollen or seed.

**Disease Cycle:** Beet mosaic virus is common in regions where crops planted in different seasons overlap or where infected plants overwin-

ter. Although many plants in the Chenopodiaceae, Solanaceae, and Leguminosae families are hosts, wild hosts are less important than infected beet plants that overwinter or overlap with new plantings. Because of the brief retention time by aphid vectors, spread generally occurs over short distances.

**Management:** Elimination of overlapping beet crops and overwintered beets before the new crop emerges has provided successful control. Control of aphid vectors is impractical because virus acquisition and transmission times are so brief.

**Figure 11.2**

General mosaic symptoms associated with infection by some viruses.  
(Courtesy of G. Wisler, University of Florida)



## Rhizomania

**Symptoms:** Classical root symptoms following early infection include a mass of fine, hairy secondary roots that give the taproot a beard-like appearance (*Figure 11.3*). Later infections may cause roots to become rotted and constricted, resembling the shape of a wine glass (*Figure 11.4*). Because infected roots are inefficient in water and nutrient uptake, foliar symptoms resemble water stress or nitrogen deficiency. A general chlorosis or yellowing of foliage commonly occurs. Rarely, veinal yellowing with associated brown, dead, or necrotic areas of leaf tissue are observed (*Figure 11.5*). Foliage and roots of plants infected late in the growing season may appear healthy.

Diseased plants usually occur in patches in the field (*Figure 11.6*) and not as scattered individual plants dispersed throughout the field. Because the fungal vector thrives in moist areas, disease severity usually is greatest in poorly drained



**Figure 11.3**  
Bearded or hairy root symptom of beet necrotic yellow vein virus.



**Figure 11.4**  
Tap root with leaves removed to show enlarged crown, wine glass shape and longitudinal section showing vascular discoloration due to beet necrotic yellow vein virus.



**Figure 11.5**  
Systemic symptoms of beet necrotic yellow vein virus.  
(Courtesy of J.E. Duffus, USDA-ARS)



**Figure 11.6**  
Rhizomania usually  
occurs in low, poorly  
drained areas of the field.



portions of the field. Reduced water uptake by infected roots increases the tendency for soil around diseased plants to remain waterlogged, which promotes additional rhizomania development and root decay by various fungi.

**Causal Agent:** Beet necrotic yellow vein virus is the causal agent of rhizomania. The soilborne fungus, *Polymyxa betae*, serves as a vector of the virus by carrying the virus to healthy roots. Virus is often identified by serological tests of infected tissue, usually roots. Procedures for rapid detection of beet necrotic yellow vein virus directly from the soil have not been perfected; however, a bioassay procedure for detecting viruliferous *P. betae* in field soil samples has been developed.

**Disease Cycle:** Sugarbeet serves as a host to both the vector fungus and the virus. The vector fungus is relatively common in soil and, when not carrying beet necrotic yellow vein virus, usually causes little damage to the sugarbeet. Although some weeds, primarily in the goosefoot family, also serve as hosts, their role in rhizomania development is unclear.

The fungus forms two types of spores during its life cycle, resting spores and motile zoospores (*Figure 11.7*). Thick-walled resting spores (cystosori) enable both the fungus and virus to survive in soil for at least 15 years in the absence of a host. When a host is present, resting spores germinate to release zoospores that infect nearby roots. Infected roots produce additional zoospores that are released and attracted to new roots. This repeating infection cycle requires approximately 48 hours for completion and enables a rapid increase of the fungus and virus in soil when soil conditions are favorable for infection. Resting spores also form in roots and are released into soil as root tissues degrade.

Root infection is favored by relatively high soil temperatures, with an optimum of 73°F to 81°F. Infection is sharply reduced by cooler temperatures, with a minimum temperature of approximately 59°F required for germination of resting spores and infection of roots. Warm soil temperatures in the spring

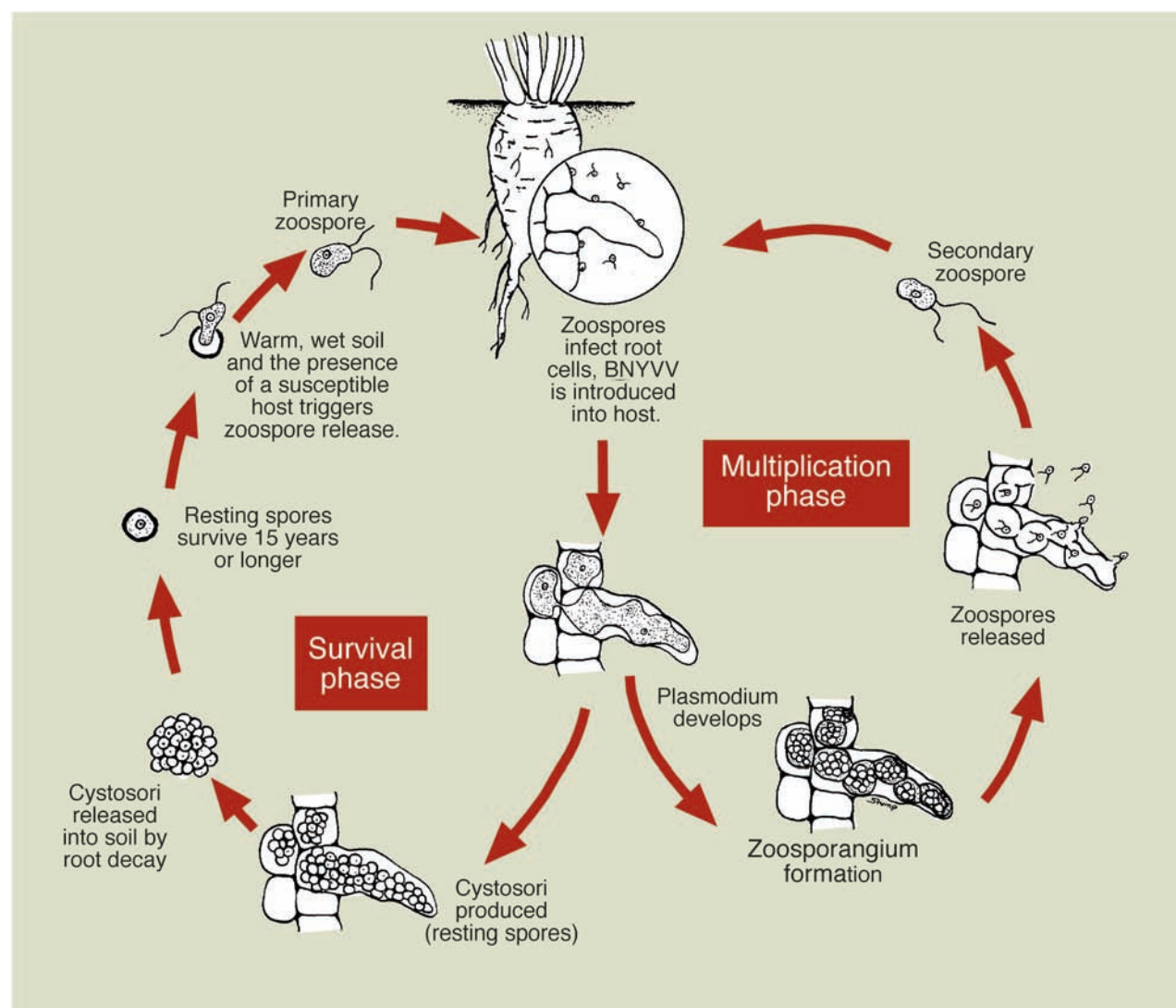
will result in earlier infection and more severe damage from rhizomania. Because zoospores require free moisture for movement to roots and infection, soil moisture at or near saturation for a prolonged period is necessary for infection and disease development. Short periods of rain in spring and early summer and use of irrigation favor fungus activity and increased rhizomania severity, provided the soil temperature is favorable. Soil pH also plays a role in disease development, with neutral to slightly alkaline soils (pH 6 to 8) favoring disease development. Coarse textured soils also may favor disease development.

**Management:** Tolerant or resistant varieties perform satisfactorily in the presence of rhizomania in some production areas, especially when combined with soil fumigation; however, each variety must be tested to evaluate its performance under local environmental conditions and production practices.

**Figure 11.7**

Life cycle of *Polymyxa beta* in sugarbeet. Rhizomania develops when zoospores carrying beet necrotic yellow vein virus (BNYVV) introduce the virus into root cells.

(Courtesy of G.D. Franc and W.L. Stump, University of Wyoming)



*Limiting the movement of infested soil is key to controlling rhizomania spread.*

Early planting, when soil temperatures are cooler, and production practices that result in the rapid establishment of the plant canopy will reduce risk of loss. Early planting should be done at a slightly greater plant density to compensate for increased seedling loss in cooler soils.

Manage soil moisture to minimize irrigation during the first six weeks following seed germination. Avoid over-irrigation and any other practices that result in standing water or excessively wet soil. Proper fertility and irrigation for the variety must be followed to reduce plant stress and further reduce the risk of disease development. Runoff water from infested fields should be contained to prevent movement of viruliferous spores to downstream sites.

Deep tillage to improve drainage also will help reduce disease risk; however, avoid unnecessary tillage operations that spread infested soil within a field. Minimize soil erosion to prevent the spread and redistribution of resting spores.

Surveys to locate infested fields will aid in controlling the spread of rhizomania. Most efforts to control the spread of rhizomania have been placed on containment — limiting the movement of infested soil into uninfested fields and production areas. Contaminating soil must be removed immediately after leaving the field because resting spores are very resistant to desiccation and are difficult to kill with chemical disinfectants, including bleach. Migrant labor, the sharing of farm equipment and the movement of cattle or other livestock among farms are several examples of how infested soil is moved. The practice of returning tare dirt to fields greatly increases the risk of spreading this virus and other soilborne disease agents. Once a field becomes infested, crop rotation will **not** appreciably reduce disease risk because of the long-term survival of viruliferous cystosori.

### Beet Soilborne Mosaic

(*Synonym: Texas 7*)

**Symptoms:** Foliar symptoms include a slight distortion, faint mottling, and light yellow vein-banding that progresses to broad chlorotic areas associated with leaf veins (*Figure 11.8*). Root symptoms vary and infected roots may appear symptomless or they may have symptoms similar to those associated with rhizomania (stunted plants, constricted taproots and proliferated secondary roots). Foliar symptoms of beet soilborne mosaic virus are rare, but do occur more frequently than foliar symptoms for beets infected by the rhizomania virus (beet necrotic yellow vein virus). When plants are co-infected with both viruses, foliar symptom expression is more frequent. Although greenhouse experiments

revealed that beet soilborne mosaic virus significantly reduced root weight compared to healthy controls, its effect on root yield and sugar production in the field has not been determined. In general, the beet soilborne mosaic virus causes milder damage to plants than that caused by beet necrotic yellow vein virus.

**Figure 11.8**  
Vein-banding symptoms of beet soilborne mosaic virus.





**Causal Agent:** Beet soilborne mosaic virus causes beet soilborne mosaic disease. Although this virus is closely related to beet necrotic yellow vein virus, it is distinctly different. Serological tests of infected tissue aid in determining which virus is present.

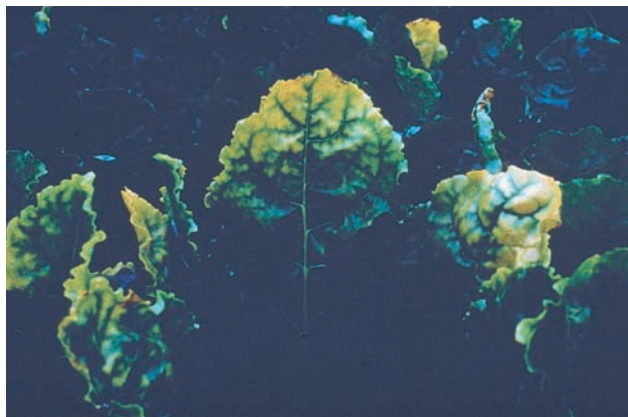
**Disease Cycle:** The beet soilborne mosaic virus is spread from plant to plant by the soilborne fungus *P. betae*, similar to transmission of the beet necrotic yellow vein virus. The disease cycles also are believed to be similar.

**Management:** Management practices recommended for beet soilborne mosaic virus are the same as those listed for beet necrotic yellow vein virus (rhizomania).

### Beet Western Yellows

(Synonyms: *beet mild yellowing virus*, *malva yellows virus*, *pea leaf roll virus*, *radish yellows virus*, *turnip mild yellows virus*)

**Symptoms:** Foliar symptoms include mild chlorotic spotting in interveinal areas to yellowing of older and middle-aged leaves starting at the leaf tip (Figure 11.9). Foliar symptoms are apparent within 30 to 35 days after infection. This yellowing will intensify, particularly under high light intensity. As infected leaves age they become thickened, brittle, and the interveinal area turns yellow while the veins remain green. Alternaria leaf spot infections commonly develop in affected interveinal areas (Figure 11.10).



**Figure 11.9**

Typical beet western yellows virus symptoms. (Courtesy of J.E. Duffus, USDA-ARS)



**Figure 11.10**

Alternaria necrosis associated with infection by beet western yellows virus. (Courtesy of R. Lewellen, USDA-ARS)

**Causal Agent:** The beet western yellows virus is an isometric virus and occurs worldwide. It is transmitted by nine aphid species, most notably by *Myzus persicae* (see *Aphids*, page 90). Virus acquisition takes approximately 5 minutes and a 12- to 24-hour period is required before transmission can occur. Virus transmission requires approximately 10 minutes of feeding. The aphid retains the ability to transmit the virus for more than 50 days. The virus persists through molts but is not transmitted to progeny. Beet western yellows virus is not transmitted through seed, foliar contact, or through pollen. There are many virus strains that have specific host ranges. Reservoir crops and sources of beet western yellows virus include beet, broccoli, cauliflower, turnip, rape, lentil,



common vetch, pea, spinach, New Zealand spinach, radish, horsebean, lettuce, pea, flax and potato. Nasturtium, phlox, petunia, bedding pansy, and zinnia are cultivated ornamental hosts. Wild hosts include mustard, pigweed, shepherdspurse, lambsquarters, *Matthiola spp.*, cheeseweed, fiddleneck, white clover, red clover, sowthistle, common chickweed, ragwort, and mallow.

**Disease Cycle:** Beet western yellows virus has a wide host range (100 species in 21 plant families) and survives between sugarbeet crops on both annual and perennial cultivated and wild hosts. The virus is spread by aphids in a persistent manner over relatively long distances.

**Management:** In areas where risk of infection by this virus is great, plant resistant varieties adapted to the production area. Place new plantings as far away from virus sources as possible.

## Diseases Caused by Bacteria

### Diseases Caused by Bacteria

Bacterial leaf spot or leaf blight  
Beet vascular necrosis and rot

### Bacterial Leaf Spot or Leaf Blight

**Symptoms:** Bacterial leaf spot or leaf blight symptoms consist of dark brown to black leaf spots or streaks on leaves. Leaf spots may coalesce, giving a blighted appearance to affected leaves. The bacterium also may enter leaves through hydathodes, resulting in a large spreading angular necrotic lesion with a yellowish margin (*Figure 11.11*). Although symptoms consist primarily of leaf spots, petioles or the seedstalks of the beet also may be affected. The bacterium also may cause a seedling blight. Although the disease is common in some areas, bacterial leaf spot or leaf blight is seldom an economic problem on sugarbeet.

**Causal Organism:** *Pseudomonas syringae* pv. *aptata* is a Gram negative bacterium that produces fluorescent colonies on Kings medium B. On nutrient agar, colonies are white, circular and smooth with entire margins. The bacterium is motile by polar multitrichous flagella.

**Disease Cycle:** The bacterium survives on living host tissue or in plant debris. It typically infects through wounds created by farming practices, abrasion or by insects, but also may enter leaf margins through hydathodes. Warm temperatures of 77°F to 86°F and moist conditions favor disease development. Hosts include sugarbeet, bean, eggplant, lettuce and pepper.

**Management:** No field control strategies have been developed; however, some seed treatment fungicides may reduce seedborne inoculum and seedling blight. Disease incidence also may be reduced by planting seed free of the pathogen.

**Figure 11.11**  
Typical foliar lesion of bacterial leaf spot or leaf blight.



## Beet Vascular Necrosis and Rot

**Symptoms:** Foliar symptoms include black streaks along the petioles, a white froth in the center of crowns, and wilt following severe root rot (Figure 11.12). Root symptoms vary from soft to dry rot, and vascular bundles become necrotic. When the root or base of the infected petiole is cut to expose the necrotic vascular bundles, surrounding areas turn pink or reddish within 20-30 seconds (Figure 11.13). Although infrequent, the disease may be severe enough to cause economic loss.



**Figure 11.12**  
Typical root rot symptoms of beet vascular necrosis and rot.



**Figure 11.13**  
Root symptom and pink discoloration caused by beet vascular necrosis and rot.

**Causal Agent:** *Erwinia carotovora* subsp. *betavascularum* is a Gram negative, motile bacterium. Colonies are strongly pectolytic on crystal violet pectate medium.

**Disease Cycle:** The bacterium may overwinter in volunteer beets and has been recovered from weeds. Injury to the crown or leaves appears necessary for infection to occur. Disease development is favored by warm temperatures of 77°F to 86°F. The bacterium does not appear to be carried in seed. Young plants are more susceptible to infection than older plants, and excessive nitrogen fertilization favors disease development. Wide spacings that encourage rapid plant growth also predispose plants to infection. Host plants include sugarbeet, carrot, potato and tomato.

**Management:** Avoid cultivation practices that injure the plant. Avoid excessive nitrogen fertilization. Cultivar resistance has been identified and may prove useful in production areas where the disease is prevalent; however, resistance must be appropriate for local strains (races or pathotypes) of the bacterium.

## Diseases Caused by Fungi Affecting Roots

### Aphanomyces Root Rot and Black Root

**Symptoms:** Aphanomyces root rot is unique in that it can cause severe problems in both the seedling stage and as a root rot of mature beets. Black root refers to the acute phase that affects sugarbeet seedlings. Symptoms of black root begin as grayish, water-soaked lesions on hypocotyls (stems) near the soil level. These symptoms are similar to flea beetle larval damage (see page 86).

### Diseases Caused by Fungi Affecting Roots

Aphanomyces root rot and black root  
Phytophthora root rot  
Pythium root rot  
Rhizoctonia root and crown rot  
Rhizopus root rot  
Fusarium root rot

**Figure 11.14**

Threadlike hypocotyls characteristic of black root acute seedling phase following infection by *Aphanomyces*.



These lesions turn black and plants often break at the site of these constricting black cankers. Infection can extend up to the cotyledons, causing hypocotyls to become black and thread-like (*Figure 11.14*). Cotyledons seldom wilt before advanced stages of the disease, so this is a primary diagnostic symptom along with the thin, dark hypocotyls.

The chronic root rot phase is characterized by foliage that wilts, turns dull green and eventually becomes yellowed (*Figure 11.15*). Plants may recover at night and regain turgor, but are more prone to wilt again during the day. Leaves may take on a scorched appearance and become brittle.

**Figure 11.15**

Dull green color of newer leaves followed by yellowing and wilting of older leaves due to *Aphanomyces* root rot and black root.



Root symptoms begin as yellowish-brown, water-soaked lesions that extend into the interior of the root (*Figure 11.16*). As disease advances, lesions become dark brown to black. Infection can occur anywhere on the tap root, but usually occurs as a tip rot. In severe cases, the entire root may disintegrate,

leaving only crowns and strands of vascular tissue (*Figure 11.17*).

**Figure 11.16**

Yellowish-brown internal lesions at early stages of infection by *Aphanomyces*.  
(Courtesy of C.M. Rush,  
Texas Agricultural  
Experiment Station)



**Causal Agent:** *Aphanomyces* root rot and black root are caused by the soilborne fungus *Aphanomyces cochlioides*. The fungus spreads by movement of infested soil and locally by means of asexual zoospores. The fungus also produces sexual spores known as oospores. Oospores are circular, thick-walled structures capable of surviving for long periods in soil (*Figure 11.18*).

**Disease Cycle:** Disease is initiated when soils become warm and wet. Under these conditions, the overwintering resting spores (oospores) germinate and can infect plants directly or infection can occur by the zoospores. Zoospores can swim

independently through soil water, hence the requirement for very moist soils.

Black root does not result in rotted seeds or affect initial stand establishment, but it can affect stands several weeks after emergence by stunting, reducing seedling vigor, or killing plants. If conditions become unfavorable for further disease development, plants may recover and go on to produce a normal



crop; however, even if they survive initial infection, the thin, delicate stems are very susceptible to breakage by spring winds.

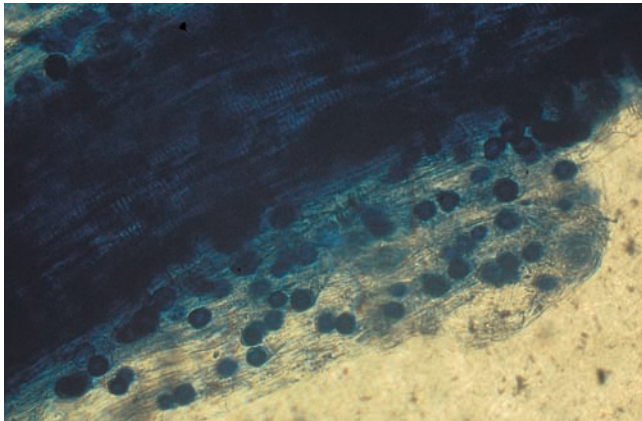
The chronic root rot phase can start and proceed any time during the season. Disease severity and intensity depends largely upon available soil moisture and temperature. High temperatures and free water are needed for germination and dissemination of zoospores. Infection has been reported to occur in soils ranging from 64°F to 90°F, but optimum is about 77°F. If soils drain rapidly or become cool, infected plants may recover, but still may be stunted, discolored, or produce dry, scabby lesions (Figure 11.19). In drier soils, infection may still occur lower in the profile as roots reach areas of higher moisture.

Several common weeds serve as hosts for the pathogen, including pigweed, lambsquarters, and kochia.

**Management:** There are no locally adapted cultivars with specific disease resistance to *A. cochliformis*; however, several cultivars are available that appear to have an overall tolerance to the pathogen. Plant early into cool soils to establish a crop before the pathogen becomes active. Plant high quality seed treated with the fungicide Tachigaren (hymexazol) to protect seedlings from the acute black root phase. This protection will last four to six weeks after emergence, but will not provide season-long protection.



**Figure 11.17**  
Tap root symptoms characteristic of severe *Aphanomyces* root rot and black root.



**Figure 11.18**  
*Aphanomyces* oospores embedded in epidermal tissues.



**Figure 11.19**  
Scabby superficial lesions following infection by *A. cochliformis*.



Avoid unnecessary irrigation of infected plants because this may cause the disease to become more severe. Do not evaluate plants for moisture stress in the afternoon because both infected and healthy plants may be wilted. In general, avoid any plant stress because this can make plants more susceptible to this disease. Any practice that creates a vigorous, well-established crop more rapidly will reduce potential disease problems.

### Phytophthora Root Rot

**Symptoms:** Initial symptoms appear as temporary wilting during the day. In later stages, leaves wilt permanently and do not recover. Small black spots are observed at the base of the taproot, and as the disease progresses, a wet rot extends upward toward the crown. In advanced stages, rotted tissue turns brown and a margin of black tissue is evident between healthy and diseased root tissue (*Figure 11.20*). Entire roots may become completely rotted and die.

**Figure 11.20**  
General *Phytophthora*  
root rot symptoms.



**Causal Agent:** The causal agent for this disease is the fungus *Phytophthora drechsleri*. It is a soilborne fungus that can be spread by motile zoospores in soil

water. Infection can occur when zoospores are released from sporangia or when sporangia germinate directly to infect roots. The pathogen also reproduces sexually to form oospores. Oospores and asexually produced chlamydospores can survive adverse soil conditions for several years.

**Disease Cycle:** The fungus survives in soil as chlamydospores or oospores and becomes problematic when soils become warm and wet. Optimum soil temperatures for infection and disease development are between 80°F and 85°F. The disease usually develops only in very wet, poorly drained soils or in low spots where soils are saturated for long periods. It also can develop in irrigated fields during very hot weather.

**Management:** Losses can be prevented by cultural practices that reduce high levels of soil moisture for long periods. These include planting into raised beds, tillage practices that promote drainage, and avoiding excessive irrigation.

### Pythium Root Rot

**Symptoms:** Beets affected by *Pythium* exhibit symptoms similar to those of *Rhizoctonia* root rot. These include sudden and permanent wilting with petioles that become water-soaked and discolored. Root symptoms include dark brown to black lesions covered with white mycelium (*Figure 11.21*). These lesions can expand to cover the entire root surface. The dark lesions produced by *Pythium* penetrate into the root and cause a wet internal rot (*Figure 11.22*) while *Rhizoctonia* lesions are primarily confined to the external surface of the root until advanced stages of disease. Roots infected by *Pythium* often have a rubbery “feel” that is not present with *Rhizoctonia*.

**Causal Agent:** Pythium root rot is caused by the fungus *Pythium aphanidermatum*. This pathogen produces zoospores which serve as the primary mode of dissemination and infection through soil water. Another species of *Pythium*, *P. deliense* has been reported to cause a root rot of mature beets in Arizona and Texas. Both pathogens produce oospores as the surviving structure in soils. The two species can be distinguished by differences in morphological characteristics, but not by root disease symptoms.

**Disease Cycle:** *Pythium* overwinters in soil as oospores. As soils warm during late spring or early summer, oospores germinate, grow and begin to infect the plant. *Pythium* causes disease problems at both the seedling stage and as a root rot of mature plants. It can attack seeds and kill them before emergence under high soil moisture conditions and it can induce postemergence damping-off of young seedlings. High soil temperatures (greater than 80°F) and moisture favor the root rot stage. This disease has often been problematic in California and Arizona where beets are grown over the winter and harvested in late spring.

**Management:** Management strategies are similar to those used for Phytophthora root rot. Avoid practices that promote high soil moisture for long periods of time. To protect initial stand establishment, apply the fungicide Tachigaren (hymexazol) or Ridomil (metalaxyl) to seed; however, a fungicide treatment will not protect plants for the entire season.

### Rhizoctonia Root and Crown Rot

**Symptoms:** The first symptoms observed are sudden and permanent wilting of leaves and a black necrosis of petioles starting at the crown (*Figure 11.23*). Wilted plants seldom recover, and



**Figure 11.21**  
External lesion on root surface caused by Pythium root rot.  
(Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Figure 11.22**  
Wet, black rot penetrating into root interior following infection by Pythium.  
(Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Figure 11.23**  
Permanent wilting of infected plant caused by Rhizoctonia root and crown rot.



**Figure 11.24**

Death of petioles and leaves following crown infection by *Rhizoctonia*.



**Figure 11.25**

Small, elliptical, dark lesions on root surface typical of infection by *Rhizoctonia*. (Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Figure 11.26**

Cross section of root infected by *Rhizoctonia* showing rot being restricted to outer portion of root. (Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



after dying they form a dry, dark rosette (Figure 11.24). Infection on roots begins as discrete, dark brown or black lesions that may grow together and cover the entire root surface as the disease progresses (Figure 11.25). Infections start most commonly in the crown and move down the root, although they

may start anywhere under the ground before spreading. Roots affected by *Rhizoctonia* usually remain firm. Rot advances across the root surface and seldom penetrates far into the interior until very advanced stages (Figure 11.26). A clear margin is usually visible in a cross section between diseased and healthy tissues. Roots with extensive rot also will exhibit cracks on the surface (Figure 11.27). After defoliating beets at harvest, holes in the ground within rows will often be observed where plants have been killed and completely rotted away by the *Rhizoctonia* root and crown rot pathogen.

**Causal Agent:** *Rhizoctonia solani*

AG2-2 causes *Rhizoctonia* root and crown rot. This organism is widely distributed in soils worldwide, and induces root diseases on many crops. The fungus grows vegetatively throughout soils by thin strands of tissue called hyphae. The fungus does not produce spores, but does produce survival structures called

sclerotia and bulbils that are compacted masses of hyphae. Genetic relationships between strains are determined by their ability to fuse in culture, and are called anastomosis groups (AG). Different *Rhizoctonia* root and crown rot groups are generally host specific and cause disease on different plants. For example, the *Rhizoctonia* AG that causes disease on wheat is the same one that causes sugarbeet seedling damping-off, but is different from the *Rhizoctonia* AG causing root and crown rot of sugarbeet. Another disease of sugarbeet called dry rot



canker is caused by *R. solani*, but is caused by strains different from those that cause root and crown rot.

#### Disease Cycle:

The fungus overwinters in soil and plant debris as hyphal fragments, sclerotia or bulbils. The fungus becomes active when soil temperatures approach 78°F to 90°F. Seedling disease may occur if beets are planted late into warm soils. Under conditions of high humidity, certain strains also may induce a foliar blight. *Rhizoctonia* can occur and cause disease in almost any type of soil, but is typically most severe in heavy soils that do not drain well, or in field depressions where water pools. Infection commonly results when cultivation deposits soil into beet crowns.

**Management:** Plant resistant cultivars adapted to the region. Seed treatments with various fungicides will help protect seedlings from damping-off. Minimize cultural practices that introduce contaminated soil into the crowns. Several fungicides are effective for protecting crowns from infection. Crop rotation with corn or small grains reduces the number of pathogen survival structures in soil. Weed control is important in reducing the disease since several common weeds such as pigweed are also susceptible to *R. solani* AG2-2. In general, sound agronomic practices that promote good crop health are recommended, including proper rotation, adequate fertility levels, and tillage practices that promote soil drainage.

#### Rhizopus Root Rot

**Symptoms:** The disease first appears as wilting of foliage, which soon becomes a dry, brittle rosette of leaves similar to that caused by *Rhizoctonia* root and crown rot (Figure 11.28). Taproots are affected by gray to brown lesions



**Figure 11.27**

Cracks in root associated with advanced stages of *Rhizoctonia* root and crown rot; (right) healthy plant. (Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Figure 11.28**

Field severely affected by *Rhizopus* root rot showing wilting and drying of leaves. (Courtesy of M.E. Stanghellini, University of California at Riverside)

**Figure 11.29**

Root on the right is affected by *Rhizopus* root rot. Note that rot originated in the crown and is progressing downward. (Courtesy of M.E. Stanghellini, University of California at Riverside)



that spread downward, resulting in rotted tissue that becomes spongy (Figure 11.29). Eventually, roots become black and are covered with a white mycelium that later turns dark as sporangia develop. In advanced stages, the rot forms cavities within the root that are filled with a fluid emitting the characteristic smell of vinegar. Plants affected by *Rhizopus* root rot also may exude a frothy, white substance from beet crowns.

**Causal Agent:** *Rhizopus* root rot can be caused by two species of the fungus *Rhizopus*. Both *R. stolonifer* and *R. arrhizus* (syn. *R. oryzae*) have been isolated from diseased roots and both have been implicated

in causing the disease. These fungi are not related to the pathogen *Rhizoctonia*, and the *Rhizopus* species are distinguished from each other by slight differences in morphological characteristics and their optimum growth temperature requirements. Both are found ubiquitously in soils worldwide and are considered to be weak but opportunistic pathogens. The fungus produces spores primarily by asexual means, forming small round sporangia filled with grayish spores. Sexual reproduction and zygospore formation requires a second, distinct mating type.

**Disease Cycle:** Both species of *Rhizopus* are weak pathogens that normally cause damage only in situations where sugarbeet plants are already weakened and growing abnormally due to some other stress factor. This condition predisposes them to infection and causes disease to be more severe. Factors causing plants to be more susceptible to *Rhizopus* infection include excessive soil moisture, mechanical root wounding, or insect feeding damage. High soil temperatures of 90°F to 100°F promote infection by *R. arrhizus* while *R. stolonifer* prefers cooler temperatures ranging from 58°F to 62°F.

**Management:** Avoid mechanical injury or high levels of insect pressure, which can open wounds for pathogen entry. Use proper irrigation management or cultural practices that allow good soil drainage. Implement any techniques which promote good plant health and reduce physical stress.

**Figure 11.30**

Foliage of infected plant showing interveinal yellowing and scorching due to *Fusarium* root rot. (Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



### **Fusarium Root Rot**

**Symptoms:** Foliar symptoms associated with *Fusarium* root rot include wilting, yellowing, interveinal chlorosis, and severely scorched leaves (Figure 11.30). Root symptoms are characterized by a distinctive, jet black tip rot of the major tap root, with similar rot



symptoms on secondary roots (*Figure 11.31*). This is the major difference observed between this disease and Fusarium yellows. Fusarium yellows produces symptoms which are restricted to wilting, yellowing of foliage and vascular necrosis, but no external rotting of the tap root. Both foliar and external root symptoms of Fusarium root rot may easily be confused with those of *Aphanomyces* root rot; however, the dark vascular necrosis of internal root tissue is diagnostic for Fusarium (*Figure 11.32*).

**Causal Agent:** Fusarium root rot is induced by *Fusarium oxysporum* f. sp. *radicis-betae*. This fungal pathogen differs genetically from the Fusarium yellows pathogen. Both are similar morphologically and form resting spores called chlamydospores and both produce two types of asexual spores called microconidia and macroconidia. No sexual stage has been identified; however, because of the genetic differences and the different symptoms caused by the two *Fusarium* pathogens, the root rot pathogen has been assigned an additional form species name.

**Disease Cycle:** The fungus overwinters in soil as chlamydospores and can survive for long periods without a host. Under favorable environmental conditions, chlamydospores germinate and initiate infection. Symptoms first become apparent as ambient temperatures begin to rise, but actual infection probably occurs much earlier. Sugarbeet infected with *Fusarium* are adversely affected because the pathogen moves into and blocks the water conducting tissues, causing the plant to wilt. Plants regain turgor at night, but wilt quickly as temperatures increase during the day. Spores are continually formed and spread further up into the plant through the vascular stream. As more vascular tissue becomes blocked, the plant has more difficulty recovering at night, resulting in older leaves wilting permanently and dying. Newer leaves become yellowed and scorched due to the restriction of water translocating into the foliage. Plants infected severely with *Fusarium* seldom recover, in contrast to those affected by *Aphanomyces*. Chlamydospores are quickly formed in rotted root and vascular tissues and are released into the soil as plants die and decompose.



**Figure 11.31**  
Severe tip rot symptoms of Fusarium root rot.  
(Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Figure 11.32**  
Vascular necrosis characteristic of Fusarium root rot.  
(Courtesy of C.M. Rush, Texas Agricultural Experiment Station)



**Management:** Some tolerant cultivars are available and can help reduce disease severity and pathogen buildup in soils. No chemical fungicides are available for control of this pathogen, so control measures must consist of sound agronomic practices like those discussed for *Aphanomyces* root rot. These include crop rotation, early planting, judicious water usage, proper fertility, and weed control. In general, these techniques attempt to reduce plant stress and modify the environment to favor the crop and disfavor the pathogen.

## Diseases Caused by Fungi Affecting Foliage

Alternaria leaf spot  
Cercospora leaf spot  
Phoma leaf spot  
Powdery mildew

## Diseases Caused by Fungi Affecting Foliage

### Alternaria Leaf Spot

**Symptoms:** Irregular to circular, brown to black lesions are usually found on older leaves first (*Figure 11.33*). Plants infected with beet western yellows virus or plants suffering nutrient deficiencies are most susceptible. Lesions caused by *Alternaria brassicae* are typically zonate while those caused by *A. alternata* are typically found only in interveinal leaf tissue on plants infected with beet western yellows virus. Leaf spots coalesce to create large areas of dead tissue (*Figure 11.10*).

**Causal Agent:** *A. alternata* is typically a weak parasite that infects yellowed portions of older leaves. The fungus produces dark, microscopic muriform spores (9-42 x 6-16  $\mu\text{m}$ ) borne in chains. *A. brassicae* causes a zonate leaf spot on older leaves under cool temperatures of 45°F to 50°F and high humidity conditions. Spores are dark, microscopic muriform (20-100 x 8-18  $\mu\text{m}$ ) and are either borne singly or in chains of two to three spores. The disease typically disappears when conditions warm or humidity drops.

**Figure 11.33**

Foliar lesions caused by Alternaria.



**Figure 11.34**

Foliar Cercospora lesion.



### Disease Cycle:

*A. alternata* is a common saprophyte on decaying organic materials. *A. brassicae* attacks horseradish, cauliflower, cabbage, broccoli, rape, turnip, mustard, Chinese cabbage, radish and related weeds. Both fungi survive on infected host residues and spores are windborne.

### Management:

Except for plants also infected with beet western yellows virus, these fungi are not economically important. In England fungicide sprays have increased yield on plants infected with the beet western yellows virus.

## Cercospora Leaf Spot

**Symptoms:** Lesions initially occur on older leaves and then progress to younger leaves. Lesions are 1/8 inch in diameter at maturity and appear light-colored to dark tan, with brown to purple margins (*Figure 11.34*). Severely affected leaves yellow, wither, and die, while remaining attached to the plant. Yellowing and rapid leaf death is due to toxins produced by the fungus. Lesions also form on petioles and will appear elongated rather than circular. A diagnostic feature of *Cercospora* leaf spot is the presence of tiny black dots (stromata) that form near the center of older lesions. Stromata are visible with a hand lens and, during periods of high moisture, will appear fuzzy due to the presence of abundant conidia. Sunken, circular lesions also have been described on sugarbeet crowns not covered by soil. Economic loss results from reduced root weight, reduced extractable sugar yield, increased loss to molasses during extraction, and reduced safe-storage times.

**Causal Agent:** *Cercospora beticola* produces conidiophores (spore-producing structures) that grow out of stromata. Conidiophores produce conidia (spores) that are generally minute needle-shaped (2-3 x 36-107 µm), colorless, and have 3 to 14 cross-walls. Conidial morphology will vary greatly with environmental conditions. Although considerable genetic variability exists in the fungus population, there is no known sexual stage of the fungus.

**Disease Cycle:** Stromata formed in mature lesions are resistant to drying and enable the fungus to survive in plant residue from season to season. When moisture is sufficient, new conidia are formed on stromata. Conidia subsequently spread and infect new host leaves. Most spread occurs via wind and rain-splash. Fungus survival also may occur via conidia carried in residue and on seed. Weed hosts such as lambsquarters, pigweed, mallow and bindweed also may be sources of inoculum. Tablebeet, sugarbeet, Swiss chard, most wild *Beta* species, and spinach, are hosts of *C. beticola*.

Severe losses occur if inoculum overwinters near fields planted to susceptible varieties and the crop canopy experiences long periods of leaf wetness accompanied by warm temperatures. Optimum conditions are 77°F to 95°F with night temperatures above 61°F and a relative humidity of 90 percent to 95 percent. Infection is greatly reduced, or does not occur, at temperatures less than 59°F or during periods of less than 11 hours of leaf wetness. The time between infection and spore production is 7 to 21 days. This long incubation period may result in large differences between “total disease” and the amount of “visible disease” observed in the field during crop scouting.

**Management:** Susceptible varieties should not be planted within 100 yards of last year’s infected crop to reduce dispersal of conidia from last year’s residue into the new crop. Tillage buries infected sugarbeet residue and decreases inoculum carryover. Three-year rotations to nonhost crops also will significantly reduce inoculum carryover. Resistant varieties may perform well under conditions of mild to moderate disease pressure. *Cercospora* leaf spot will progress more slowly on resistant varieties, reducing, but not necessarily eliminating, the need for supplemental fungicide application. Information on varietal resistance is available from sugar companies and reports of variety trials conducted in the various production regions. The need for fungicide is based on varietal susceptibility, the availability of inoculum, and the presence of conditions favorable for disease development. It is important to monitor environmental conditions

which determine when periods favorable for infection occur and to apply fungicide accordingly. The most effective *Cercospora* leaf spot management program will integrate multiple methods for disease control and will have the first fungicide application in place immediately prior to the onset of disease.

The *Cercospora* leaf spot fungus is known to develop resistance or tolerance to certain fungicides following repeated fungicide exposure. It is essential to follow resistance management programs that rely on multiple fungicide chemistries with different modes of action. This can be accomplished either by applying them as tank-mixes or by alternating fungicide chemistries during sequential foliar applications. Although foliar fungicides will not totally suppress *Cercospora* leaf spot, they will delay the onset of disease and, once disease develops, will slow the rate of disease development in the plant canopy.

### Phoma Leaf Spot

**Symptoms:** Leaf spots are light brown and round to oval (1/2 to 1 inch in diameter) with dark concentric rings near the indefinite margins (*Figure 11.35*). Dark colored pycnidia can be seen scattered through the lesion or in concentric rings. Disease intensity is usually greatest on lower leaves. On seed stalks, lesions appear as brown to black necrotic streaks with grey centers containing black pycnidia.

The root rot phase of this disease includes damping-off of young seedlings. Infected seedlings have a dark brown canker on the hypocotyl and after plant death black pycnidia can be seen in the cankered area under wet conditions. After the tap root is established, small dark brown depressed areas develop on the crown portion of the root. A dark brown to black watery soft rot initiates in these lesions. Later these areas become coal-black and shriveled. White mycelium in cavities and pycnidia are commonly present at this stage. Where root rot occurs, the leaves wilt rapidly and rot can continue in storage piles.

**Causal Agent:** The fungus *Phoma betae* (perfect stage *Pleospora bjoerlingii*) is the causal agent. Pycnidia are black, ostiolate and lenticular to globose in shape and partially engulfed by host tissue. Pycnidiospores are hyaline, one-celled and vary in size. The perfect stage is found in lesions in the fall. Perithecia are black, and hemispherical with muriform, pale yellow-green ascospores.

**Disease Cycle:** The fungus is seedborne and survives in infected crop or lambsquarters residues for up to 26 months. During wet conditions pycnidio

spores are exuded from pycnidia and dispersed by splashing water. Ascospores are wind-borne. Damping-off is favored by low temperatures and wet conditions during germination and emergence. The leaf spot and root rot phases of the disease are favored by wet condi-

**Figure 11.35**  
Foliar Phoma leaf spot lesion.





tions and temperatures between 59°F and 90°F.

**Management:** Use a three- to four-year crop rotation with adequate phosphate fertility. Plant disease-free seed treated with an effective fungicide. Where the root rot phase is prevalent, minimize the storage time from harvest to processing.

### Powdery Mildew

**Symptoms:** Symptoms first appear on older, lower leaves as small, dispersed radiating whitish mats (*Figure 11.36*). The fungus grows on the surface of leaves and leaves appear to have been dusted

with flour (*Figure 11.37*). The fungus spreads rapidly over the upper, and sometimes the lower surfaces of leaves, until all leaves appear dusty white. The underlying leaf tissue may become chlorotic, eventually taking on a purplish hue. A loss of one to two tons per acre is common. The greatest losses occur in fields where infection occurred early and disease was allowed to progress unchecked.

**Causal Agent:** Powdery mildew is caused by the fungus *Erysiphe polygoni*. Although many crop and ornamental plants have powdery mildew disease, this fungus only attacks sugarbeet and garden beet.

**Disease Cycle:** Powdery mildew usually appears during mid to late August, but may occur as early as mid-July. The fungus does not appear to overwinter in the High Plains; instead, spores blow northward from infected plants in the southern regions of the United States. Spores land on leaves, germinate, and symptoms appear within several days. It spreads rapidly and most leaves are infected by harvest time. Disease severity generally increases with age of the plant at the time of infection. Although disease development is more rapid when plants are well supplied with water, water stressed plants suffer greater loss due to rapid death of infected and less-turgid leaves.



**Figure 11.36**  
Early powdery mildew lesion.



**Figure 11.37**  
Severe powdery mildew infection.

**Management:** Foliar fungicide applied at the first signs of disease are most effective at suppressing disease spread. Experiments in western Nebraska revealed that if the fungicide application was delayed for two weeks, the yield advantage was reduced by one-half. Resistant cultivars are available, although most disease management is through the use of fungicides.

## Wilt Diseases

Fusarium yellows  
Verticillium wilt

## Wilt Diseases

### Fusarium Yellows

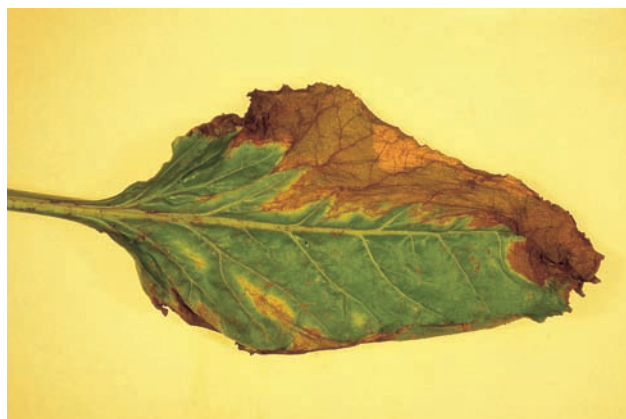
**Symptoms:** Leaves show wilting (yellowing) between veins and often only one side of the leaf is initially affected (*Figure 11.38*). Older leaves tend to show symptoms first. There are no external root symptoms, but internal vascular tissues have a brown discoloration. This can be seen by cutting the root tangentially and observing the vascular tissues (*Figure 11.39*). As leaves wilt they become dry, brown and brittle, collapsing in a heap around the crown. Petioles are generally tan as opposed to the chocolate brown of leaves killed by *Rhizoctonia*. Where soil inoculum is high and warm conditions predominate, seedling damping-off can occur. In seed production fields rapid seed stalk wilt can occur. Symptom development is strongly influenced by temperature. Little symptom development occurs below 50°F to 59°F with most pronounced symptoms developing above 75°F. Coinfection with sugarbeet cyst nematode or water stress will increase disease severity.

**Causal Agent:** Fusarium yellows is caused by the soil inhabiting fungus

*Fusarium oxysporum* f. sp. *betae*. In culture the fungus produces large numbers of both intercalary and terminal chlamydospores, large numbers of slightly curved microconidia and relatively few macroconidia. There does not appear to be races of this fungus although isolates vary widely in their virulence.

**Figure 11.38**

Unilateral and interveinal wilt symptoms associated with Fusarium yellows.



**Figure 11.39**

Discoloration of internal vascular tissue associated with Fusarium yellows.



### Disease Cycle:

The fungus survives between crops as chlamydospores or macroconidia. Once soil is infested it will remain so and even long rotations are not effective. Anything that moves infested soil will spread the pathogen.

**Management:** Grow resistant cultivars adapted to the production region. Maintain three- to four-year rotations to avoid building up inoculum. Maintain optimal soil moisture and manage sugarbeet cyst nematode. Avoid moving infested soil by equipment or other means.

### Verticillium Wilt

**Symptoms:** Older outer leaves become straw colored, wilt and become dry. Younger inner leaves are yellowed, narrow and have deformed petioles. Infected plants are stunted. When infected taproots are cut in cross section, infected vascular elements appear as fine brown threads. Vascular discoloration is much less pronounced than with *Fusarium* yellows.

**Causal Agent:** This disease is caused by the soil inhabiting fungus, *Verticillium albo-atrum*. The fungus survives as dark thickened mycelium and microsclerotia for long periods in the absence of host plants. There are more than 200 plant species that serve as hosts, although there are fungus isolates that have specialized host ranges. The fungus produces verticillate conidiophores with hyaline conidia, dark hyphae and microsclerotia.

**Disease Cycle:** Roots are infected through wounds and systemic infection occurs via the vascular system. Inoculum is produced in vascular tissue and is returned to the soil when host tissue rots. Because of the broad host range, rotations need to be planned carefully.

**Management:** Maintain rotations of three to four years or more, avoiding other hosts if possible. Avoid introducing the fungus in infected planting stock of other host crops (e.g. infected potato tubers, tomato transplants, etc) or via infected alfalfa or mint hay.

## Diseases Caused by Nematodes

### False Root Knot Nematode

**Symptoms:** Fields may be uniformly infested, but severe damage usually only appears in localized areas. Young plants may be severely stunted or killed, resulting in early season loss of stand. Top and root growth are severely reduced throughout the season. In mid- to late season severely infected plants may exhibit leaf wilting during the warmer parts of the day. The most visible symptoms on the roots are galls or swellings with a proliferation of side roots (*Figure 11.40*). This contrasts with the northern root-knot nematode that produces smoother galls. The false root-knot nematode also produces starch granules in feeding areas inside the galls that can be seen as dark flecks when gall sections are painted with an iodine-potassium iodide solution. By slicing through the galls in a dish of shallow water the adult female can be teased out and observed. Using a low power microscope the female can be seen as tapered at both the anterior and posterior ends, resembling a sweet potato shape. This contrasts with females of root-knot nematodes that are rounded at their posterior end forming a rough pear shape.

**Causal Agent:** The false root-knot nematode (*Nacobbus aberrans*) was first described on sugarbeet in western Nebraska in 1956; however, it is now known to have been present in this region much earlier. It is a pest of sugarbeet and several other host crops in Montana, Wyoming, Nebraska and Colorado. Al-

### Diseases Caused by Nematodes

False root knot nematode  
Lesion nematodes  
Root knot nematodes  
Sugarbeet cyst nematode  
Stubby root nematodes



**Figure 11.40**

Early infection of sugarbeet by *Nacobbus aberrans* causes large galls on tap root and adventitious roots. Infected young plants may die.



**Figure 11.41**

Gall formation on kochia roots at point of infection by *N. aberrans*.



though a native to this region (occurring in rangeland areas remote from cultivated fields), it has not spread throughout the sugarbeet production areas as intensely as the sugarbeet cyst nematode, *Heterodera schachtii*. Nevertheless, *N. aberrans* causes severe damage to sugarbeet in highly infested fields.

**Disease Cycle:** Most of the population live through the winter as eggs which hatch when the growing season begins. Juveniles penetrate the roots, frequently just behind the root tip, and lie coiled within root galls that form around them. After the second molt they become juvenile males and females and many of them migrate from the roots into the soil. The immature females enter other roots and force their heads among the cells near the central cylinder. Increased cell division occurs around the nematode forming root galls. Several females may be found inside a single gall. Numerous small rootlets grow from the gall. The posterior portion of the female extends outward and a small opening is formed in the outside of the gall where a gelatinous matrix containing eggs is extruded by the female.

Economic hosts in addition to sugarbeet include broccoli, cabbage, carrot, cucumber, lettuce, pea, pumpkin, radish, rutabaga, tomato, and turnip. Common weed hosts are kochia, common lambsquarters, Russian thistle, common purslane

and puncturevine (Figure 11.41). The nematode also occurs on prickly pear cactus on western Nebraska rangeland.

**Management:** There are no resistant sugarbeet cultivars for the false root-knot nematode; however, planting early when soil temperatures are relatively cool reduces damage from *N. aberrans*. The younger the plant when parasitism occurs, the greater the injury and yield loss. In general, a combination of rotation with non-host crops, good weed control, early planting of infested fields, and use of nematicides is necessary for satisfactory control of the false root-knot nematode.

Weed hosts should be controlled along irrigation laterals, canals and in other crops grown in a rotation. Crop rotation will reduce nematode populations. Dry bean, corn, small grains, alfalfa, and potato are not hosts for *N. aberrans* in this region and can be used in rotations to reduce populations enough so that susceptible crops can again be produced. Four- to six-year rotations may be necessary. For crop rotation to be effective, it's essential that

weed hosts be controlled in all crops in the rotation. Nematicides may provide adequate control of *N. aberrans* to grow a satisfactory crop of sugarbeet. A dependable economic threshold level for false root-knot nematode populations in soil has not been established, so soil testing is of limited value for determination of the need for applying nematicide. Soil fumigant nematicides may not provide satisfactory control of the false root-knot nematode in soils containing undecomposed infested roots of newly harvested crop or weed hosts. Tare soil from sugarbeet harvest should not be returned to fields used for sugarbeet production. Trap crops such as oil radish and yellow mustard have shown no effect on populations of the false root-knot nematode. Instead, these trap crops were developed specifically for control of *Heterodera schachtii*.

## Lesion Nematodes

**Symptoms:** When large numbers of lesion nematodes congregate in root cortex tissue, discolored or rotted lesions may occur. These lesions may be associated with fungus invasion of roots; however, they are not thought to cause significant injury to sugarbeet in the High Plains.

**Causal Agent:** Root lesion nematodes are distributed throughout this tri-state region and are often reported in nematode analysis results from soil samples. *Pratylenchus neglectus* appears to be the most common species, but *P. scribneri* and other species also are present in some fields. There has been little indication in the North Platte Valley that the root lesion nematodes are a factor in sugarbeet production. Observations in several field plot experiments have indicated that populations do not increase significantly on sugarbeet during the cropping season. In a corn-bean-sugarbeet rotation, lesion nematode population levels are the lowest during the year of sugarbeet production. Significant yield losses occur in corn and sometimes in dry bean, but no sugarbeet yield losses have been reported in this region. In affected crop species, injury level may vary among species of root lesion nematode. Thus, species identification is an important management tool.

**Management:** Root lesion nematode management on sugarbeet has not been shown to be economical in the High Plains.

## Root Knot Nematodes

**Symptoms:** Infected plants may be stunted and have chlorotic leaves. Severely infected plants may wilt during the heat of the day. Root-knot nematodes attack fibrous roots and taproots and induce the formation of root galls. A single gall may contain one to several nematodes. Invasion of storage roots in mid-summer results in a warty appearance on the root surface. Galls formed by the northern root-knot nematode are usually round. Fungal root rots often follow root knot nematode infections.

**Causal Agent:** *Meloidogyne hapla*, the northern root knot nematode, is the most widely distributed root-knot nematode species observed on sugarbeet in Colorado, Nebraska and Wyoming, but it is not usually considered a major factor in sugarbeet production in this region. It is not as aggressive on sugarbeet as the sugarbeet nematode, *Heterodera schachtii*, or the false root-knot nematode, *Nacobbus aberrans*. The most destructive root-knot nematodes on sugarbeet in the United States are *M. incognita* and *M. javanica*, but they have not been reported in this region. The Columbia root-knot nematode, *M. chitwoodi*, can

**Figure 11.42**

Field heavily infested with the sugarbeet cyst nematode. Left, normal growth of sugarbeet in soil treated with a nematicide; right, thin stands of stunted sugarbeet growing in soil with no nematicidal treatment.



**Figure 11.43**

White adult sugarbeet cyst nematode females attached to adventitious roots of sugarbeet.



cause significant damage to sugarbeet but, though it may be present in small areas of this region, it has not been observed here on sugarbeet.

**Disease cycle:**

Root-knot nematodes overwinter in the soil or in host root tissue. The second stage larvae enter the roots of sug-

arbeet and complete their life cycle inside the root galls formed after infection. They go through four molts to become adults within about 20 to 25 days. Several generations may develop during a growing season. One female can produce as many as 1000 eggs.

**Management:** In-furrow granular nematicide and soil fumigants provide control of root-knot nematodes. Nematicides will be less effective in situations where galls remain on plant roots that are not decomposed. Because of their wide host range, control by crop rotation may be difficult. The various species have different host ranges that must be considered in control by rotation. Identification of species is important since *M. hapla* is easily controlled by rotation with corn, grasses, or cereals and these rotations are not effective for *M. chitwoodi*.

**Sugarbeet Cyst Nematode**

**Symptoms:** Fields may be uniformly infested or have one or more localized areas of infestations in circular or oval areas exhibiting poor plant stands and growth (*Figure 11.42*). Seedlings may be severely injured or killed resulting in poor stands; however, the older the plant is when attacked, the less damage will occur. Young plants attacked by *H. schachtii* have elongated petioles and remain

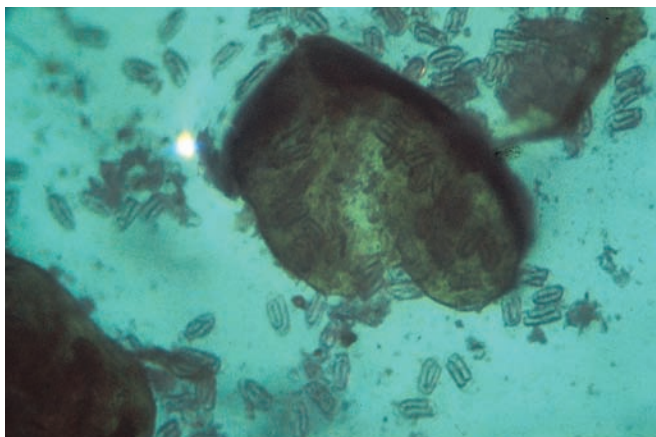


stunted until harvest. Outer leaves of infected plants usually wilt during the hot period of the day. Plants that are severely attacked have pronounced yellowing of the leaves. Affected plants have small storage roots and excess fibrous roots that often are referred to as “bearded” or “whiskered.” Early attack of roots often causes severe branching of storage roots. When older plants are attacked or infection severity is low, symptoms are less noticeable. The most easily recognized sign of infection is the adult females attached to the roots. They are white to pale yellow, typically lemon-shaped and approximately 1/32 inch in length. They are easily seen with the aid of a hand lens (*Figure 11.43*). The amount of damage caused by the sugarbeet cyst nematode depends largely on the number of nematodes and the length of favorable environmental conditions. Damage to plants is greatest in a dry summer following a wet warm spring.

**Causal Agent:** The sugarbeet cyst nematode, *Heterodera schachtii*, was reported as early as 1907 in Colorado and in 1926 in the North Platte Valley of western Nebraska. Today, *H. schachtii* is present in economic threshold levels in most of the older sugarbeet production areas of Colorado, Montana, Nebraska, and Wyoming. It is continually contaminating sugarbeet fields in newer production regions.

**Disease Cycle:** *H. schachtii* overwinters as eggs and juveniles. They remain dormant inside the cyst, which is the body of the dead female. When the root of a host plant grows near the cyst, soil moisture is sufficient and soil temperatures are 50°F or greater, root exudates stimulate juveniles to hatch and emerge from the cyst. Juveniles are attracted and migrate to the fibrous roots, infecting near the root tips. After entering the root, they develop into swollen sausage-shaped third stage juveniles. After a fourth molt the adult female becomes lemon-shaped and may be seen as a small white dot attached to fibrous roots. Adult males enter the soil and are attracted to the females where fertilization occurs. Typically, one female produces over 200 eggs. Most eggs remain inside the female. When the female dies, her body wall hardens and is transformed into a light brown to reddish brown, lemon-shaped cyst, completing the cycle (*Figure 11.44*). The life cycle requires four to six weeks depending on soil temperature. Three cycles have been reported to occur during the growing season in western Nebraska. Reproduction can occur between 50° and 90°F with optimum temperatures for reproduction between 70°F and 80°F.

Cysts, containing eggs and/or juveniles, may remain viable in irrigated fields for several years. Annual rate of decline of egg and juvenile populations in soil during rotation usually ranges from 40 percent to 60 percent. Survival or rate of decline is influenced by soil temperature, soil moisture, presence of susceptible plants (including cultivated crops and weeds), soil type and the number of predators and parasites pres-



**Figure 11.44**  
Sugarbeet cyst nematode eggs released from a crushed brown cyst.

*Sugarbeet cyst nematode is present at economic levels throughout most of the High Plains.*

ent. Preplant egg and juvenile populations in soil usually range from 0 to 15 per cubic centimeter (approximately one teaspoon) of soil in a corn-bean-sugarbeet cropping sequence. Higher numbers are found in shorter rotations. The economic threshold level was determined in western Nebraska in the early 1990s to be about 2.8 eggs (including juveniles) per cubic centimeter of soil. Several factors influence the economic threshold level. A higher sugar price, higher percent sugar and lower cost of control will lower the economic threshold level. Conversely, a lower sugar price and percent sugar and higher cost of control will raise the expected economic threshold level. A grower may want to consider these factors and vary the expected economic threshold level from two to five eggs per cubic centimeter of soil.

In this region, *H. schachtii* causes economic losses primarily in sugarbeet, but it can attack over 200 plant species in 23 plant families. In addition to sugarbeet, other host crops include turnip, kale, radish, spinach, broccoli, cabbage, cauliflower, tomato, Brussels sprouts, table beet, kohlrabi, rhubarb and other closely related crops. Weed hosts include mustard, pigweed, lambsquarters, shepherdspurse, purslane and other closely related weeds. Good weed control is crucial during rotation to obtain maximum reduction of soil populations of *H. schachtii*.

Cysts are found in the soil profile from the surface down to 24 inches. The greatest concentration is usually found in the root zone (2 to 10 inches). Cysts may spread in many ways. Long distance spread has most likely been from cysts in soil peds in unclean seed. Contaminated soil on machinery, animal hooves, etc., also can result in long distance spread of *H. schachtii*. Short distance spread occurs through irrigation water such as through a canal system or in surface water within a given field. Cysts may move in wind-blown soil and in feces of birds and other animals. At harvest, many cysts attached to roots are shaken off during unloading at beet dumps and infested tare soil may contaminate trucks returning to other farms. Tare soil shaken from harvested roots may have egg populations as much as 100 times greater than usually found in soil collected from infested fields (*Figure 11.45*).

**Management:** A combination of rotation with non-host crops, good weed control, sanitation, and planting a trap crop, when practical, will all contribute toward reduction of *H. schachtii* soil populations. Laboratory analysis of soil should be made to determine nematode density, when sugarbeet can safely be planted, and the need for a nematicide application.

**Figure 11.45**

Tare soil from cyst nematode infested fields contains enormous numbers of fresh egg-filled cysts.



Resistant sugarbeet cultivars are not available, but certain breeding lines appear promising. Planting early when soil temperatures are relatively cool (below 60°F) greatly reduces dam-

age from *H. schachtii*. Nematicides are useful, particularly in short rotations and when egg populations are above the suggested threshold prior to planting sugarbeet. Preplant soil fumigant and at-plant granular nematicides are labeled for control of *H. schachtii* on sugarbeet. Soil fumigants must be applied in the fall or pre-plant during the early spring. Effectiveness of fumigants depends on the depth of application, soil temperature and moisture, soil type, compaction and organic matter content. It is extremely important to follow label requirements for sealing the soil surface. Label directions for use of all nematicides must be strictly adhered to for maximum efficacy and operator safety.

Oil radish and yellow mustard “trap crops” are successfully grown in Germany to control the sugarbeet cyst nematode. In research plots and limited grower trials trap crops provided effective control in the High Plains and Inter-mountain Region of the United States. Roots of the trap crop mimic those of a host crop by producing root exudates that stimulate eggs to hatch and attract juveniles to the roots. After penetration, however, juveniles fail to develop into adults and reproduction does not occur. Trap crops, when used in conjunction with rotation to a non-host crop, should further lower the soil population of *H. schachtii* and reduce the need for a nematicide.

In western Nebraska, oil radish and yellow mustard planted between May 15 and August 15 reduced sugarbeet cyst nematode population levels as effectively as chemical nematicides. They need approximately 10 weeks growth at soil temperatures above 50°F to be effective. Thus mid-summer growth is most desirable. Trap crops should be planted in narrow rows with a grass drill at a rate of at least 25 to 30 pounds per acre to get a thick stand. Thick stands are necessary to encourage prolific lateral root development throughout the soil profile where cyst nematodes are most active. Thick stands also discourage weed hosts from supporting nematode reproduction in the trap crop. A good seedbed, thick stands, and adequate irrigation are necessary for success. Wyoming and Nebraska field studies revealed that oil radish and mustard trap crops had no effect on the false root-knot nematode. Growers should be aware of mixed populations of those two nematode species when choosing control methods. Economics of a trap crop production system should be carefully determined and compared to the cost of conventional chemical control of the sugarbeet nematode.

Rotation of sugarbeet with non-host crops such as wheat, barley, corn, bean or alfalfa will reduce the soil population of *H. schachtii* through natural decline; however, weed hosts must be controlled in all crops in the rotation. The number of years of rotation out of sugarbeet will depend on the density of cysts in the soil. In a heavily infested field a rotation of three to four years is minimal.

Avoid dumping tare soil into fields as this practice can result in “hot spots” for the cyst nematode, as well as *Rhizoctonia* root rot and other sugarbeet diseases and pests.



## Stubby Root Nematodes

**Symptoms:** Stubby root nematodes are ectoparasites that feed on root tips and cause the formation of stubby-ended lateral roots resulting in shortened, branched root systems. The stubby root nematode transmits tobacco rattle virus and in one field in the North Platte Valley, several stubby root nematodes per cubic centimeter of soil were associated with a high incidence of this virus disease on sugarbeet (*Figure 11.46*). Stubby root nematodes also have been associated with stunted corn plants and potato corky ringspot in this region.

**Causal Agent:** Stubby root nematodes, *Trichodorus* spp., feed on roots and also transmit the tobacco rattle virus. Low populations of the stubby root nematode are frequently associated with sugarbeet in the North Platte Valley. Though it is an economically important pest on sugarbeet in parts of Europe, it is rarely important in this region.

**Figure 11.46**

Foliar symptom associated with infection by tobacco rattle virus.



### Disease Cycle:

The stubby root nematode completes its life cycle within about three weeks, depending on soil temperature. It can complete several life cycles per season. All life stages appear to survive the winter in soil. Root development is affected starting with seedling stages and continu-

ing throughout the season. In this region, however, it is seldom recognized as a serious problem on sugarbeet and tobacco rattle virus symptoms on sugarbeet are rare.

**Management:** Control practices have not been developed for the stubby root nematode on sugarbeet in this region because it is seldom implicated as a serious pathogen on this crop. Chemical nematicides reduce population levels but rapid reproduction appears to quickly replace normal populations. Stubby root nematodes have a wide host range, thus crop rotations have little effect on population levels.

By *C. Dean Yonts and Karen L. Palm*

## Goal of Irrigation

**S**ugarbeet is a biennial crop with first year growth used to maximize root yield and store sugar while the second year is dedicated to seed production. Sugarbeet are grown in the Central High Plains for the production of sugar rather than seed, therefore this discussion will focus on optimum irrigation management techniques for sugar production. Some annual crops can tolerate limited plant water stress without a significant influence on yield. This is generally the case for crops producing seeds like corn or drybean. The water requirements for sugarbeet are similar to irrigated alfalfa in that plant water stress slows the production of biomass which directly impacts final production. Since total sugar yield is related to root production and maximum root production is related to limiting plant stress, an understanding of water requirements and proper irrigation techniques is important for optimum sugar production.

Aside from understanding the plant's water needs, it is also necessary to understand that irrigators in the Central High Plains will have major water challenges in the future. Availability of water and the cost of obtaining water are major issues. Increased demand for water from municipalities and the need to support natural ecosystems provide competition for water that in turn can increase the cost of water or limit water supplies. A second and equally important issue is water quality. With poor irrigation management practices comes degradation of water quality. Degradation occurs primarily through increased deep percolation which leaches fertilizer and chemicals to the ground water and field runoff which can lower surface water quality. The goal of water management should be to use available water resources as efficiently as possible while maintaining water quality for other uses.

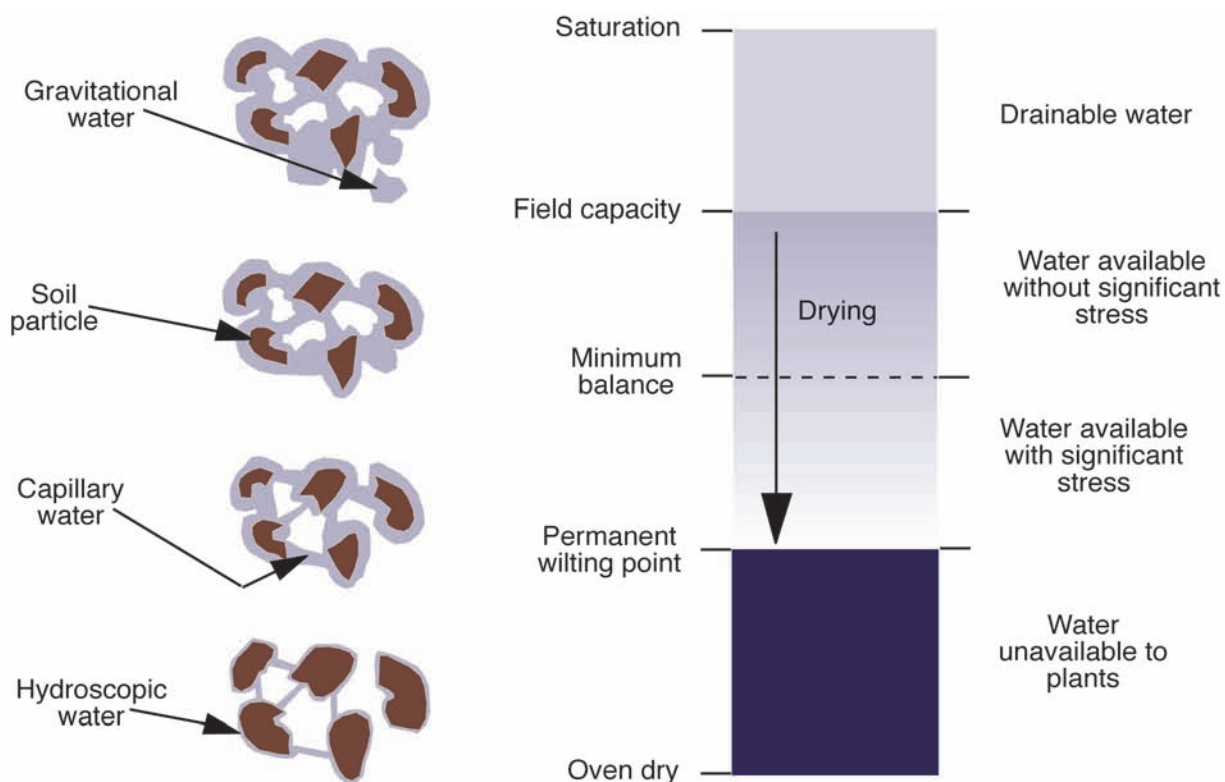
## Soil Water Characteristics

**W**ater is held in the soil much like water is held in a sponge. If too much water is added to the sponge, the water runs out the bottom. With soils, this loss of water out the bottom of the soil profile is referred to as deep percolation. When percolation occurs below the root zone, not only is water moved below where the roots can use it, but fertilizer and chemicals are taken with it and cannot be recovered. When all water has stopped draining out the bottom of the root zone, the soil is said to be at field capacity.

A single grain of sand can be surrounded by a thin film of water. By putting a multitude of these grains together, the amount of water held by the soil becomes significant (*Figure 12.1*). As soil particle size decreases, as with fine textured soil, more surface area is available for water to be adsorbed on the surface of soil particles. Thus, finer textured soil can hold more water than coarse textured soil. Not all water held around soil particles is available for plants to use. Water stored in pockets or trapped against gravity is used by the sugarbeet first because it is easiest to obtain. As roots pull more water from the soil, the layers of water on the soil particles get thinner. As this layer of water thins, the sugarbeet must use more energy to extract the water. As this process continues,

**Figure 12.1**

Soil water reservoir components.



extraction becomes harder and harder to a point where the water can be held by the soil with more strength than the plant can overcome. This is called the wilting point and is where plant death occurs.

Although plant water stress progresses gradually, irrigation should begin before more than 50 percent of the available water held in the soil has been depleted to avoid excessive plant stress. This 50 percent depletion point is referred to as the minimum balance. Soil water should be maintained above this level to avoid yield limiting water stress.

*Table 12.1* gives the water holding capacity and minimum balance for a range of soil textures. All of the available water can be used by the plant, but the minimum balance should be the most water that is used from the soil profile to avoid significant plant stress. As an example of how to use *Table 12.1* consider a fine sandy loam soil which holds 1.8 inches of water for each one foot of soil. Only 0.9 inches of this water should be used from each foot of soil to avoid excessive plant water stress. Therefore in a three-foot soil profile that is at field capacity, there are 2.7 ( $3 \times 0.9$ ) inches of water that can be used by sugarbeet without experiencing significant plant water stress.

If irrigation water is applied in excess, water application efficiency is reduced and water is lost through runoff and deep percolation. Irrigation should be used to refill the soil profile where roots are actively growing. With deep percolation and runoff, water is not only lost, but water quality may be degraded through the loss of fertilizers and pesticides (*Figure 12.2*).



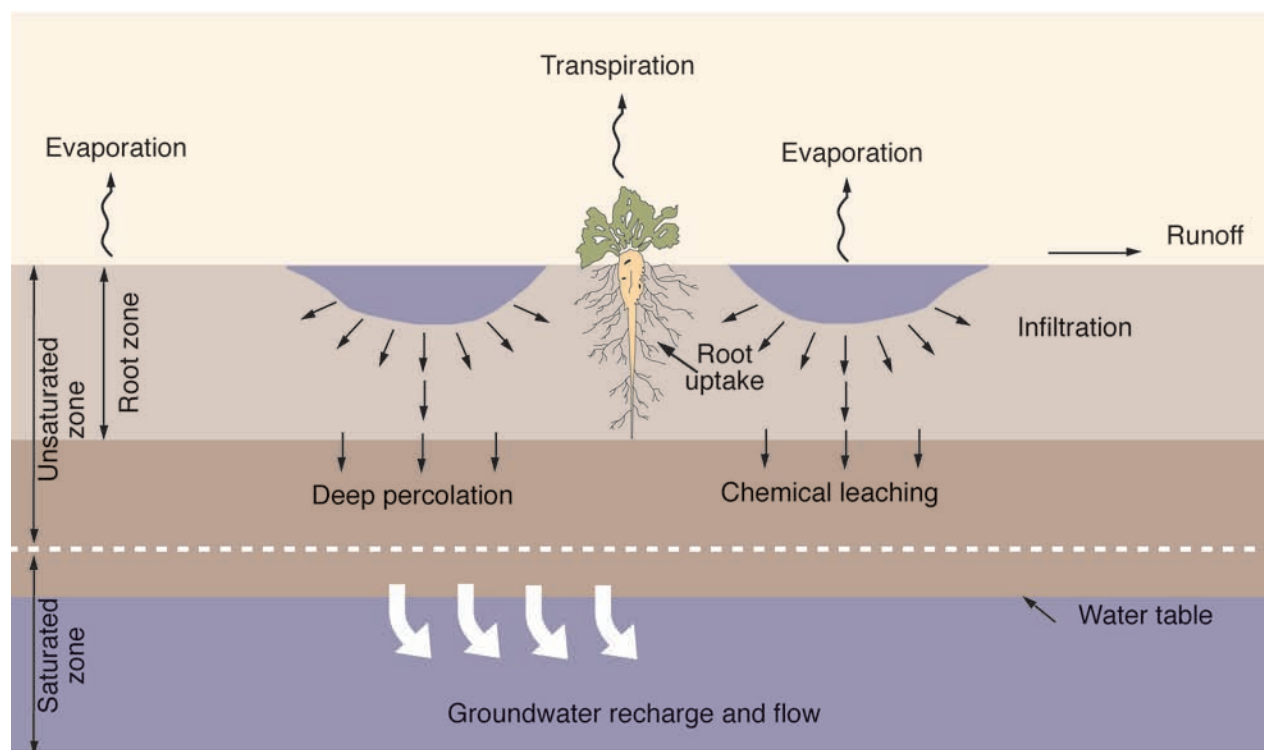
**Table 12.1**

Available water holding capacity and minimum water balance for soil textural classes.

Soil textural classification	Available water holding capacity (inches of water/foot of soil)	Minimum water available (inches of water/foot of soil)
Fine Sand	1.0	0.5
Loamy Sand	1.1	0.6
Sandy Loam	1.4	0.7
Silty Clay or Clay	1.6	0.8
Fine Sandy Loam, Silty Clay Loam, or Clay Loam	1.8	0.9
Sandy Clay Loam	2.0	1.0
<b>Topsoil</b> - Loam, Very Fine Sandy Loam, or Silty Loam	2.0	1.0
<b>Subsoil</b> - Silty Clay Loam or Silty Clay		
<b>Topsoil</b> - Loam, Very Fine Sandy Loam, or Silty Loam	2.5	1.3

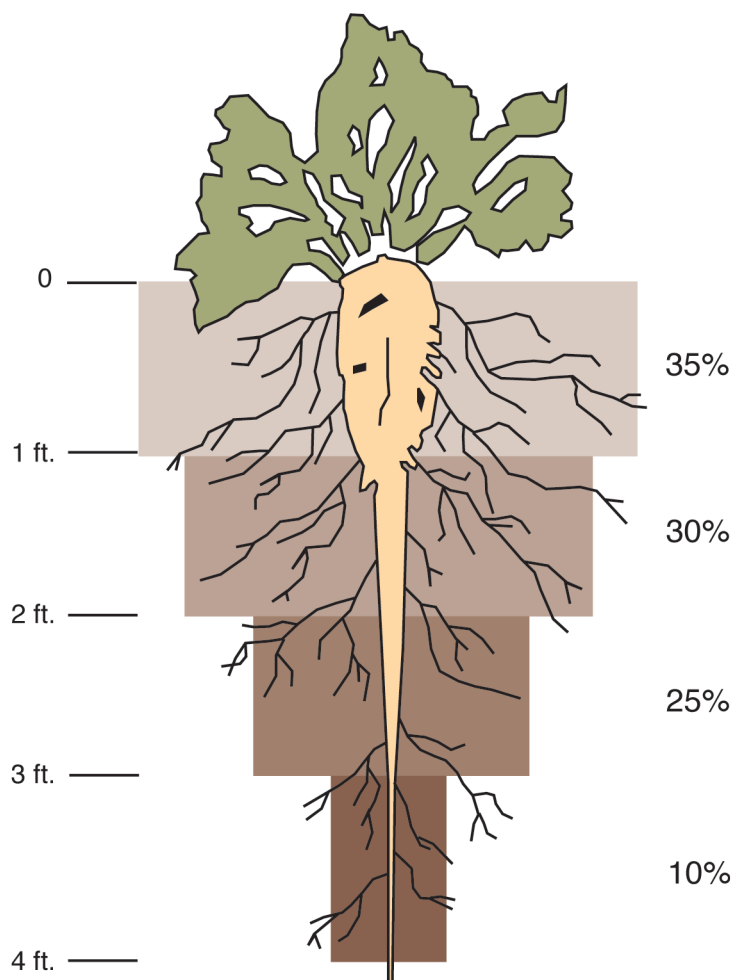
**Figure 12.2**

Irrigation water movement in the soil profile.



**Figure 12.3**

Percent water extraction in the top 4 feet of a soil profile having adequate water available. Most water uptake occurs in the top 3-4 feet of soil. As the sugarbeet extracts water and the soil begins to dry, the percentage of water extracted from the upper portion of the soil profile is reduced while the percentage of water extracted from the lower portion of the soil profile is increased.



## Sugarbeet Plant Characteristics

Plants use water through a process called transpiration. Water is taken in through the roots and moved through the plant and transpired through the leaf surface (*Figure 12.2*). When climatic conditions become hot and dry and water cannot be transpired fast enough, the plant shuts down in order to survive. This causes the plant to wilt. Irrigation may have occurred only two or three days prior, but wilting may still be observed due to extreme weather conditions. Use of a soil probe is helpful in this situation to verify that climate is in fact the cause for wilting. In some cases, soil compaction may be restricting water infiltration below a given level. What was thought to be an irrigation to fill the entire soil profile may only be filling the top foot and water stress is actually occurring.

The combination of transpiration and evaporation from the soil surface is called evapotranspiration. Early in the season the evaporation component is large in comparison to transpiration because of the large amount of soil surface exposed. After full crop canopy cover is achieved, this is reversed with transpiration being the major component. This is part of the reason for developing a full crop canopy as early in the season as possible so water can be used to meet transpiration needs. The evaporation component remains greater later into the

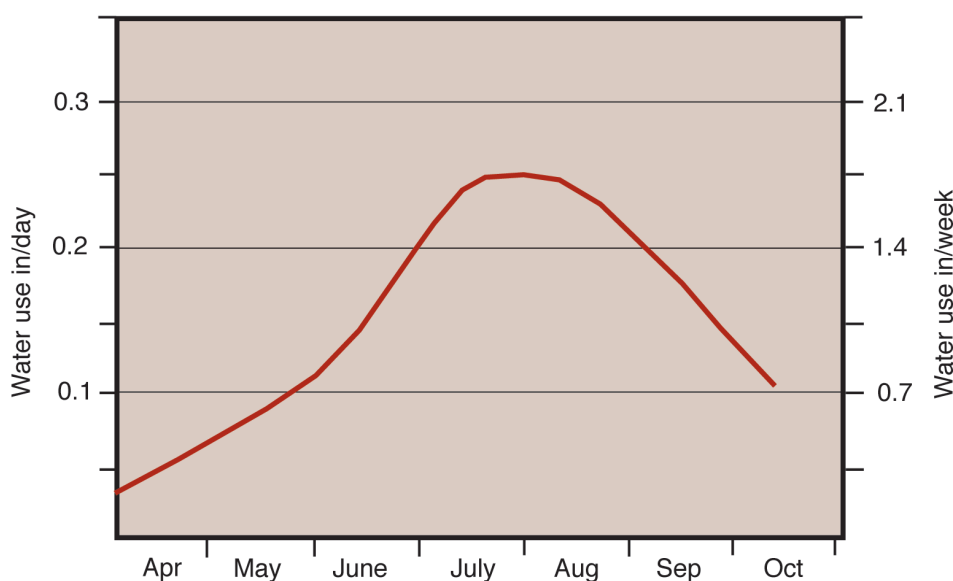
growing season if sugarbeet is planted in 30-inch rows because full plant cover is difficult to achieve and in some cases is not achieved the entire season.

The sugarbeet plant has an extensive tap root that can penetrate up to 6 feet into the soil if it is not limited by soil compaction or lack of water. A layer of dry soil will act just like a severely compacted zone of soil and limit root development. As sugarbeet roots penetrate deeper into the soil, the plant uses more energy to transpire. This is why normal irrigation management calls for depleting only the top 3 feet of the soil profile before irrigating.

Plants remove water from the easiest location in the soil profile first. This means water near the surface is used first and water stored deeper in the soil profile is used second. This process continues throughout the soil profile until water in the first foot is well below the 50 percent depletion level. Even though water can be taken from deeper in the soil profile, limiting the water management soil profile to 3 feet avoids excess water stress and provides some reserve when irrigation is delayed (*Figure 12.3*). Just as water stress early in the season can limit root development, irrigation that replenishes only the upper layer of soil discourages root development at the deeper depths of the soil profile. Poor irrigation practices or soil compaction will change where the sugarbeet root system develops and where water is obtained. Irrigation management should strive to replace water in the active root zone throughout the entire growing season.

## Sugarbeet Water Use

**P**eak levels of water use by sugarbeet will generally occur in late July and early August at approximately .25 inches of water per day (*Figure 12.4*). Day to day variation in crop water use can be extreme. Cool days at this time may result in water use of only 0.1 inch per day while during hot dry days crop water use could climb to 0.4 to 0.5 inch per day. As air temperatures decline in late August and September, plant water use declines and irrigation schedules should be adjusted to reflect less crop water use.



**Figure 12.4**

Average daily and weekly crop water use for sugarbeet during the growing season. Actual daily water use varies based on climatic conditions.



**Figure 12.5**

Weather station used to monitor crop water use.



Crop water use information is determined using weather stations (Figure 12.5) and is available from a variety of sources. These include, but are not limited to, newspapers, radio, and internet sites. The information usually provides what crop water use has been the past few days as well as a forecast of future crop water use. These values are important if irrigations are to be scheduled to meet crop demands.

*The peak period for sugarbeet water use is from late July to early August when plants use about 0.25 inches a day.*

## Early Season Water Management

If there is a critical time when irrigation can affect final yield, it is most likely to occur during germination and early plant development. Not having adequate soil water for germination and emergence can delay establishment and reduce plant populations which in turn reduce final yield. A few days of warm dry winds when root development is minimal can stress the plant for moisture and cause it to die. If soil water is not adequate and stress begins, it is often difficult to replenish the soil water in a timely fashion. Therefore, it is important to have an adequate supply of water in the soil below the seedling which allows soil water to migrate upward, replacing surface evaporation and meeting the demand of the young seedling. Withholding water early, which may reduce plant stand, can lead to poor water use efficiency for the entire growing season. Missing plants mean more bare ground, which in turn means water will be evaporated from the soil rather than transpired by growing plants.

## Late Season Water Management

In late August and September, when water use begins to decline and full root development has occurred, allowable soil water depletion levels can increase to approximately 60 percent. This means irrigation intervals can be extended without causing yield limiting water stress on sugarbeet. Severe water stress can occur more quickly on coarse textured soils with limited soil water supplies. Keep in mind that good irrigation management throughout the growing season results in the development of a good root system. A good root system, coupled with lower evapotranspiration demand late in the growing season, allows sugarbeet to be more effective in obtaining water from the entire soil profile. If water restrictions are a concern, it is critical to first establish the sugarbeet crop with available water and continue with properly scheduled irrigations during high water use periods of July and August. In this instance, water

has been used to develop an extensive sugarbeet root system that will be more efficient in meeting crop water demands later in the season. Stress late in the growing season will have less impact on final yield than water stress that limits plant development early in the growing season.

## Irrigating for Germination and Emergence

There are pros and cons to irrigating sugarbeet for germination and emergence (*Figures 12.6a-b*). The additional amount of labor and energy required is the primary reason given for not irrigating after planting; however, with irrigation, plant stand and vigor can be improved during this critical growth period. The lack of soil water during germination will often result in less than adequate plant population and seedlings vulnerable to disease. Irrigation for germination and emergence should be like any other input used in growing the crop, it must be cost effective. Water supplies are becoming too critical and too costly to not be used in a cost effective manner.

Center pivot operators are more likely to irrigate after planting because labor input is minimal; however, remember that having a center pivot does not guarantee plant establishment. During a three-year Nebraska study, sugarbeet emergence was measured for approximately 40 varieties at 20 sites in Colorado,



**Figure 12.6a-b**

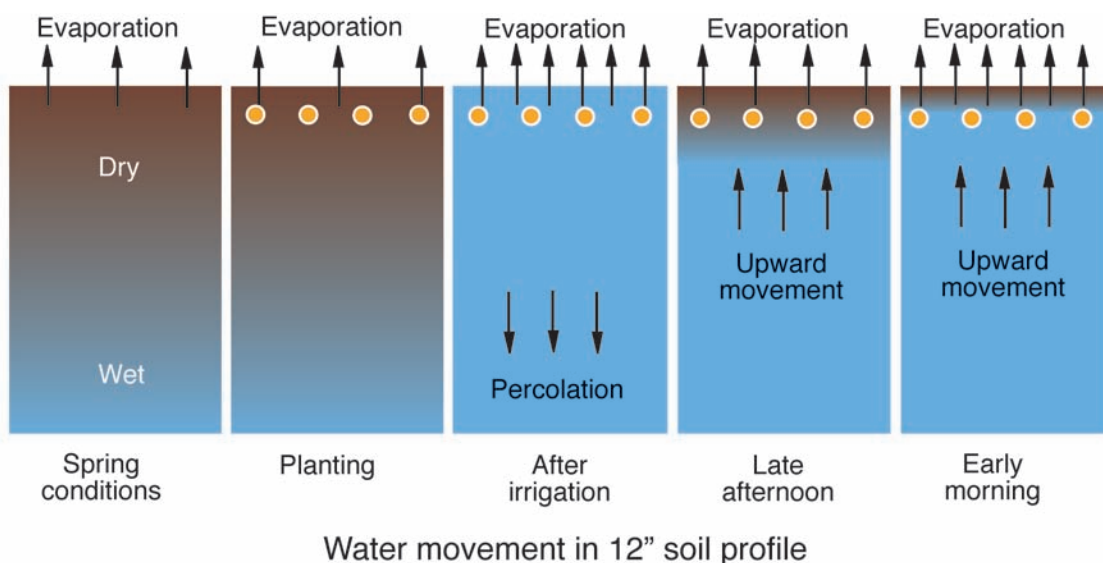
It's important that adequate water be available during sugarbeet germination and emergence. Irrigating up can provide uniform plant stands even though labor and energy inputs will increase. The amount of water in the soil determines how many plants will germinate while soil temperature determines the rate at which sugarbeet plants emerge. Eliminating water stress during sugarbeet plant establishment improves seedling vigor. This in turn allows the sugarbeet to compete with other stress factors such as disease and weeds.



Nebraska, and Wyoming. Emergence at the eleven furrow irrigated sites averaged 70 percent. Of these eleven, six were furrow irrigated up and average emergence was improved to 75 percent. The nine sprinkler irrigated sites were all irrigated up but averaged only 62 percent emergence. The center pivot system should offer better emergence, if the needs of the germinating plant are considered.

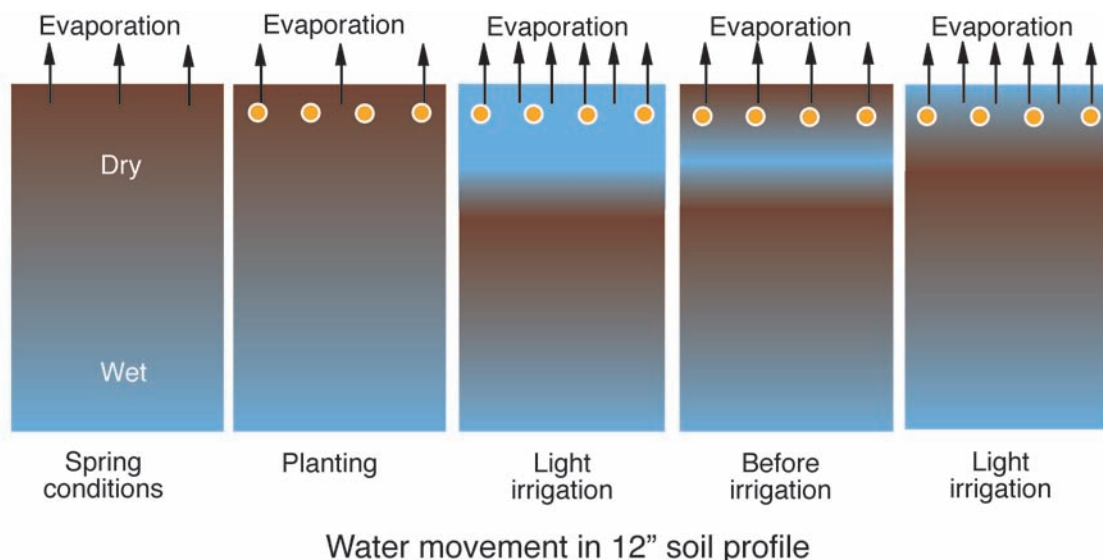
**Figure 12.7**

Furrow irrigation after planting supplies adequate soil water for germination and emergence through the upward movement of water to the soil surface.



**Figure 12.8**

With a center pivot, applying all of the water needed for germination after planting, makes it difficult to supply adequate water plus it degrades the soil surface making emergence more difficult. This illustration shows water movement with less than 1/2 inch sprinkler irrigation.





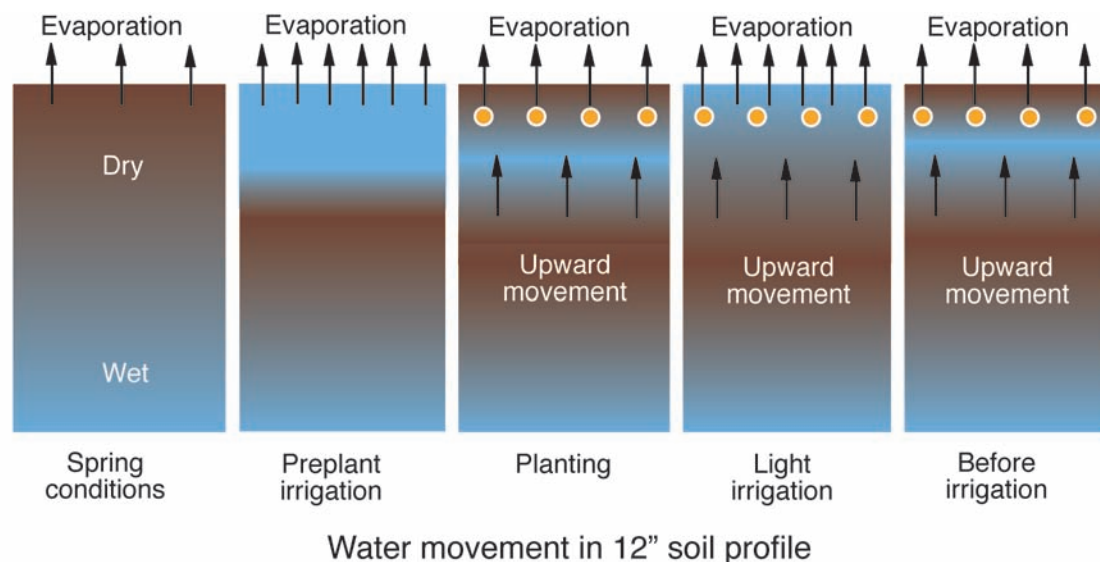
Let's examine the role of soil water and how the irrigation method can influence germination and emergence. In *Figure 12.7*, we see what happens in a furrow irrigated system where we know emergence can be good. We start with semi-dry soil conditions for spring planting. Once irrigated, however, the soil profile is filled to capacity and adequate water is available below the seed. As the soil surface dries during the day, water migrates upward to replace soil evaporation losses. As a result soil water around the germinating seed is maintained. Given that a firm seed bed was prepared, this upward movement of water in the soil continues for several days until the germinating seed begins root growth into the moist soil below.

Now let's examine the same spring situation, only this time a center pivot is used to supply water for germination and emergence (*Figure 12.8*). In this situation, irrigation is applied after planting. If a light irrigation of 0.5 inch or less is used, only a small portion of the soil profile will be filled and evaporation quickly dries the soil surface. Evaporation occurs to a deeper depth compared to the furrow irrigation example because there is not adequate soil water below the seed. The only option we have once germination has begun is to continue light irrigation applications to try and avoid excessive water stress. With each added irrigation, the soil surface becomes consolidated, making emergence more difficult and increasing the potential for soil erosion due to wind.

In *Figure 12.9*, we again have the same spring conditions, only this time the center pivot is operated before planting to partially refill a portion of the soil profile. When the seeds are planted, the soil profile has not been filled to field capacity like the furrow system, but adequate water has still been made available below the seed. Upward movement of water occurs to meet soil evaporation losses. Applying a light irrigation now will refill the entire soil profile that surrounds the germinating seed. In this scenario, applying some of the water before planting avoids repeated irrigations after planting. Reducing sprinkler irrigations after planting allows the surface soil structure to be maintained while making soil water available for germination.

**Figure 12.9**

Applying a preplant sprinkler irrigation when the soil is dry reduces the risk of seedling desiccation during germination and emergence.



*Contrary to popular belief, limiting irrigation early in the season does not drive the tap root deeper into the soil profile.*

Before adopting irrigation for germination and emergence as an every year practice, ask this question: “Have I done what is necessary to conserve precipitation that fell during the fall, winter and spring?” In the Central High Plains, precipitation varies from one growing region to another (*Figures 7.1-7.3, Chapter 7*). At a given location, the decision to irrigate or not to irrigate should be based on the amount of water in the soil at planting.

An example of one method to conserve soil water would be to create a firm bed in the fall before spring planting. The seed bed is firm yet several freeze-thaw cycles will have created a mellow seed bed at seeding depth. Soil water is below the seed and irrigation will be needed only if drying conditions exist. Compare this system to multiple tillage operations in the spring where much of the soil water that did accumulate over the fall and winter is lost to evaporation due to repeated cultivations of the soil.

## Furrow Irrigation Water Management

Labor is certainly a significant drawback to using furrow irrigation (*Figures 12.10a-c*), but investment in the irrigation system is considerably less than for a sprinkler system. In many cases the performance of furrow irrigation for germination and emergence equals or exceeds that of a sprinkler. The reason is that with furrow irrigation, adequate water is applied to the soil, the seed is thoroughly soaked, soil particles on the surface are not broken down and consolidated and as the soil warms, water is available below the seed to migrate up and meet the plant’s need for quick emergence.

Once the needs of early plant development are met, either through early irrigation or spring precipitation, the first irrigation of the season is not normally needed until late June or early July. Although not always possible, filling the soil profile to a depth of 2.0 feet is adequate for this first irrigation because root development is not much below 2.0 feet until full canopy cover has occurred. If the season allows for full canopy cover earlier than normal, irrigation should coincide with full canopy development because crop water use will be greater earlier in the growing season. Avoid delaying the first irrigation and allowing the soil to become too dry. Irrigating before severe water stress occurs will enhance furrow irrigation water advancement in the field. Contrary to popular belief, stressing sugarbeet early in the season does not “drive” the tap root deep into the soil profile. This practice merely places the plant under water stress, discourages good root development and ultimately reduces sugarbeet yield.

In most cases irrigators should try to move water down the field uniformly and make set changes every 12 hours. With fine textured soil where infiltration is slow, set times of 24 hours may be required. In these situations advance time also should be increased. A rule of thumb for water advancement in the field is to advance water in three-fourths of the total set time. For example, if irrigation set time is 12 hours, advancement to the end of the field should take approximately 9 hours. If advance time is much shorter, a large amount of water will be returned as runoff. If advancement time is much longer, there will be inadequate time for water to infiltrate into the soil profile at the lower end of the field. If a reuse system is used, advance water in one-half of the total set time.





**Figure 12.10a-c**

The first irrigation with a furrow system is often difficult, but can be made easier by implementing a few simple changes:

1) Plant sugarbeet on slightly raised beds. This makes construction of furrows easier and avoids throwing additional soil on the seed or into the sugarbeet crown.

2) Construct furrows that are firm and free of clods to allow faster water movement through the field.

3) Begin irrigating before soil water is depleted and plants are under stress. Irrigation is more difficult in extremely dry soil conditions because infiltration rate is higher, making water advance difficult.

4) Use surge irrigation to reduce infiltration and improve water advance.



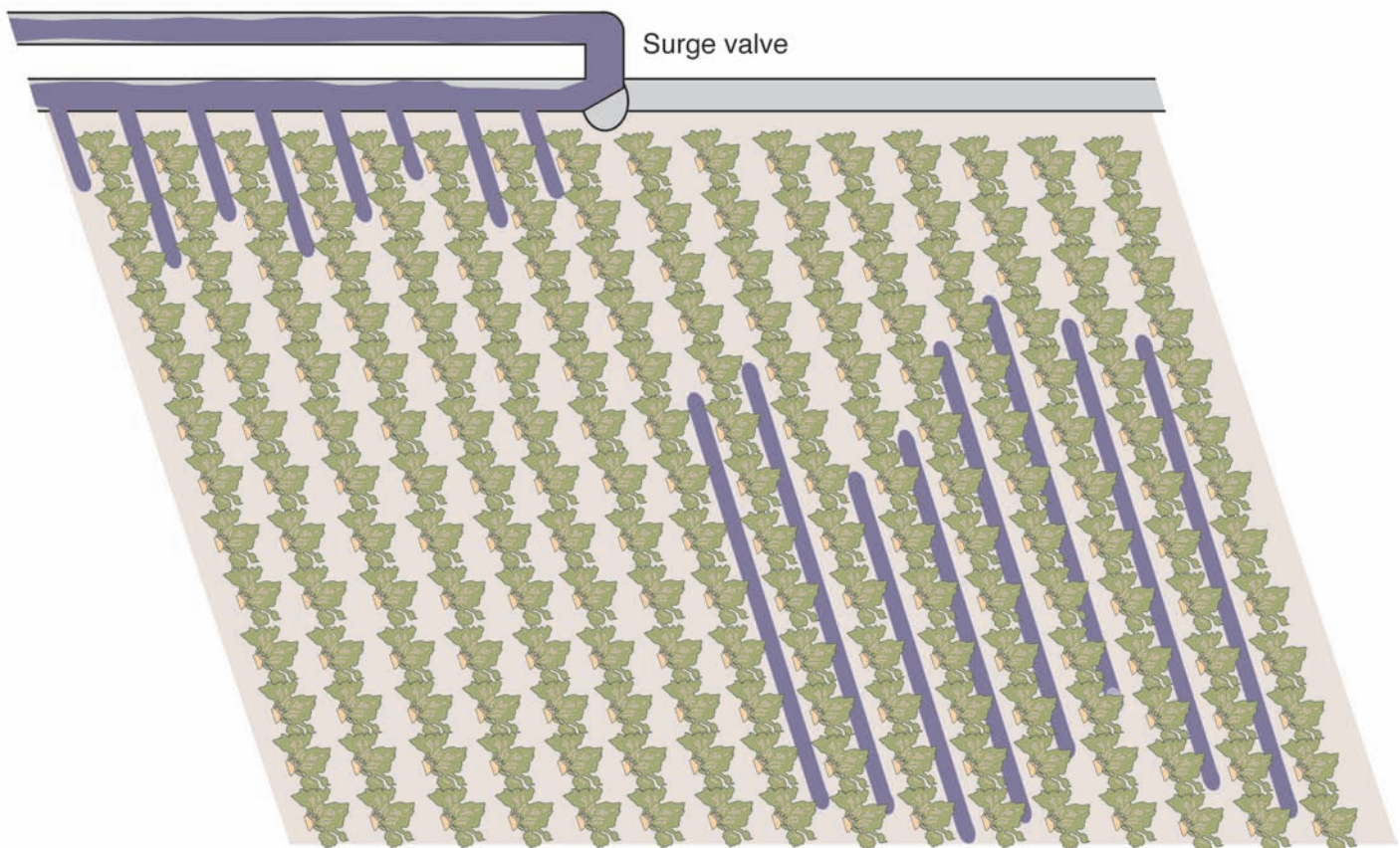


As sugarbeet leaves mature and fall into the irrigation furrow, irrigation advance can become difficult. Increasing furrow stream size may be necessary to advance water down the field. At some point furrows may be so inundated with leaves that water tends to flood and regardless of set time will not reach the end of the field. If only one irrigation is left or the affected area is small, the late season stress will likely have little impact on final yield. However, if this occurs in the middle of the irrigation season, other options such as irrigating from the center of the field or reditching to clear the leaves from the furrow should be considered.

Surge irrigation is a beneficial management tool, especially during the first irrigation and early in the growing season. By surging irrigations, advance times can be shortened and set times often can be kept to 12 hours. The pulsing or surging of water between two irrigation sets allows soils to go through several short duration wetting and drying cycles. The wetting and drying results in fine materials moving with the water to consolidate and settle on the furrow bottom in larger pore spaces. When water is reintroduced, the finer materials have filled many of the voids and the rate that water moves into the soil (infiltration rate) is reduced. This means more water is available to move down the field, thus reducing advance time.

**Figure 12.11a**

A surge irrigation system with valve located in center of field to automatically alternate water between two irrigation sets.

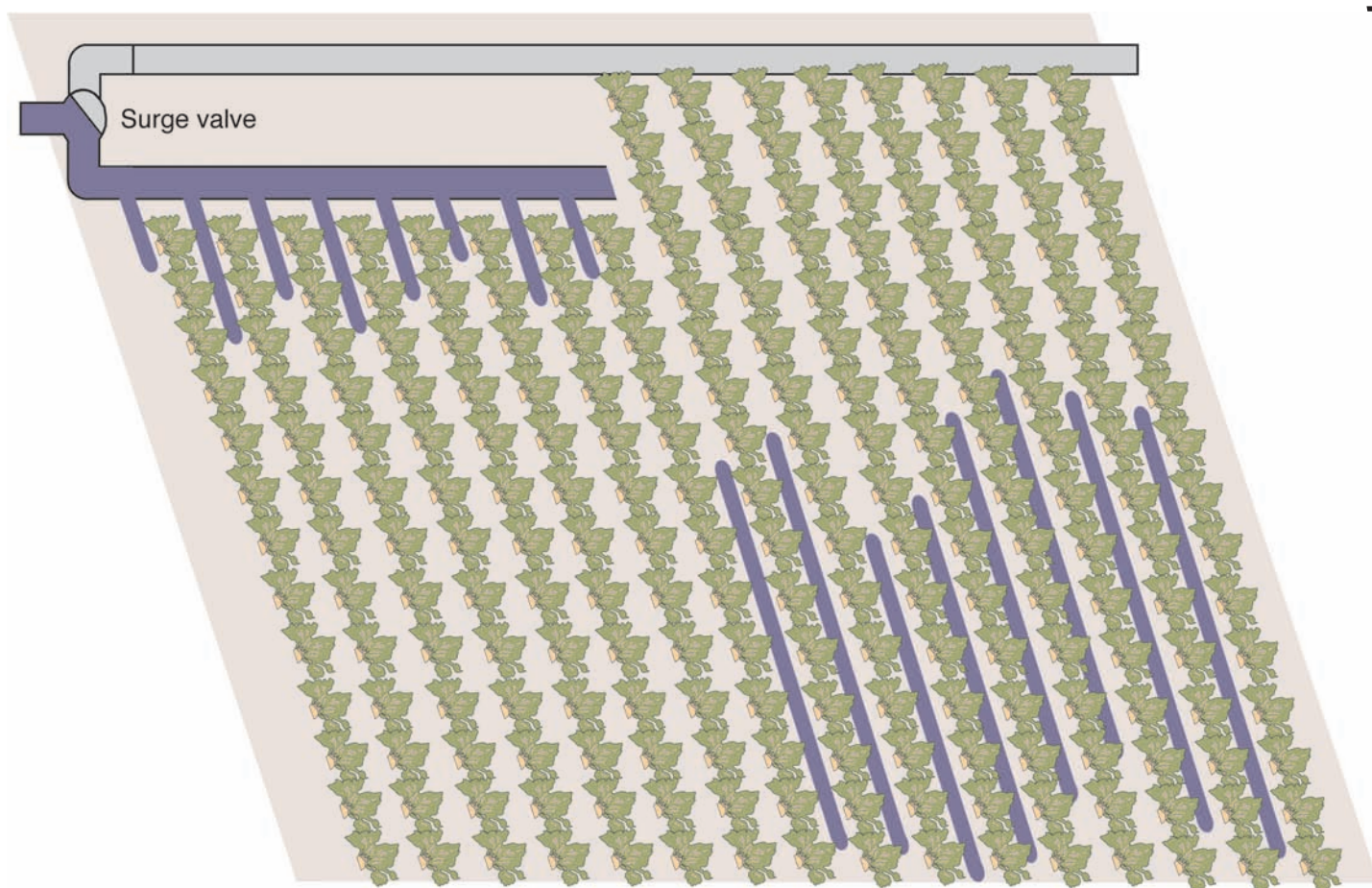


Surge irrigation can generally be used on any furrow irrigated field where gated pipe or plastic ditch can be used (*Figure 12.11a*). The surge valve is normally located in the center of the field if adequate pressure head is available in the pipe. For gravity head ditch systems, the surge valve is normally located on the uphill side of the field (*Figure 12.11b*). Two irrigation lines are laid across the head end. One line is gated pipe halfway across the field, while the second line is main line pipe halfway then gated pipe for the last half of the field.

If conditions are difficult and furrow advance is slow, particularly during that first irrigation, instead of allowing water to run with little advance, try testing surge by manually surging water down the furrows. Open and close gates or move siphon tubes back and forth between some furrows every hour and compare to flow in other furrows. Water will likely move down the field faster and will result in a more uniform application when using surge.

**Figure 12.11b**

A surge irrigation system with valve located on side of field to accommodate gravity flow conditions in the pipeline.





**Figure 12.12**  
Sprinkler irrigation of  
sugarbeet.



## Sprinkler Irrigation Water Management

**S**prinkler irrigation is often viewed as a superior irrigation method (*Figure 12.12*). Unless managed correctly, all that it may save is labor without giving any advantages to better water application and yield. The mistake often made with center pivot irrigation is not knowing the amount of water being applied and relating that value back to what is known about the evapotranspiration rate. For example, evapotranspiration is much higher for two to three days following irrigation due to increased evaporation from the soil and plant. If crop water use is averaging 0.25 inch per day, water use will increase to 0.3 to 0.35 inch per day for one to two days immediately after irrigation before returning to the before irrigation rate.

If only 0.25 inch of water was applied to help the sugarbeet become established, at least half of that amount would be lost to evaporation within three days. Therefore only about 0.10 inch of water would be available for the seedling. If this process was done twice but at a four- to five-day interval, the result would be two irrigations with only about 0.2 inch of water available to the plant. On the other hand, if 0.5 inch of water was applied, the loss will still be approximately the same, in that about 0.1 to 0.15 inch is lost to evaporation; however, since 0.5 inch was applied, 0.35 to 0.4 inch of water remains in the soil for the plant to use. This single irrigation increased water application efficiency by reducing evaporation losses. The goal of irrigation in this situation should be to move surface water down to meet water in the soil and avoid leaving a dry layer.

If sugarbeet seed is being planted into dry soil with no chance of germination, serious consideration should be given to applying a pre-plant irrigation to fill the top 1 foot of the soil profile. The advantages of pre-plant irrigation are:

- 1) available water below the seed,
- 2) better depth control while planting,
- 3) placing seed in moist soil,
- 4) no immediate post-plant irrigation required, which leaves soil particles intact to reduce potential wind erosion, and
- 5) soil temperature can return to a normal state before planting.

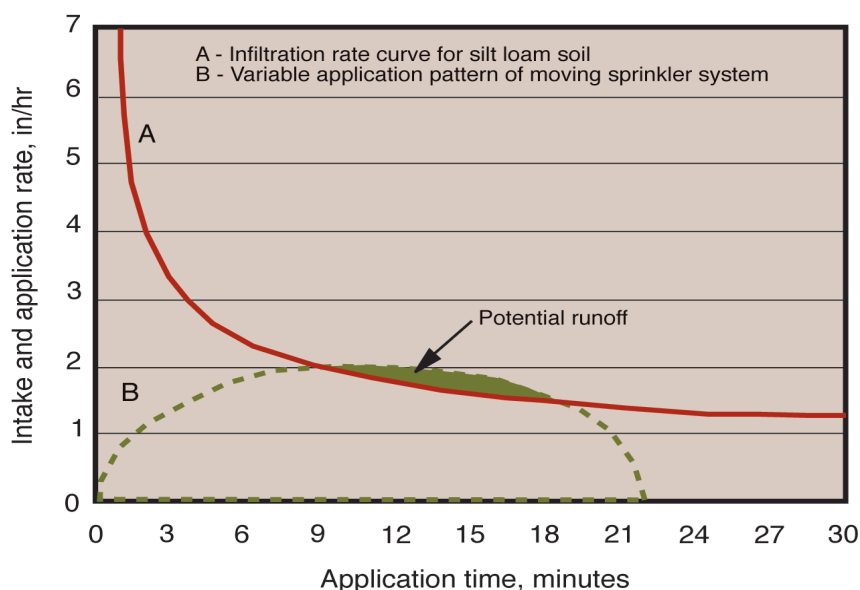


By filling the top foot of soil, adequate water is available for the seed to germinate and emerge without applying excess water after planting and creating a potential crusting problem.

Soil temperature is influenced slightly by irrigation, but the limited amount of data collected has not established whether there is an effect on plant vigor and yield. It is known that soil temperature can increase or decrease as a result of irrigation. Water that is approximately 55°F can reduce normal spring time soil temperature by 3°F to 4°F. Depending on air temperature, it will take no more than approximately five days for the soil to return to preirrigation temperature levels. If seedlings are under water stress, or germination is being threatened because of lack of moisture, the practice of not irrigating because of the fear of reducing soil temperature is not correct and can result in reduced crop stands. Consider a rain or snow event that occurs during the spring. Soil temperatures will be reduced to levels below those resulting from irrigation because snow, for example, will be at freezing temperatures.

Another aspect to consider with sprinkler irrigation is placement of sprinkler or spray devices. The industry has gone through major changes and has seen sprinkler devices placed on drops below the sprinkler pipeline and near the crop canopy in an effort to reduce water loss. It recently found that losses due to evaporation and drift from sprinkler systems is much smaller than was first estimated. Changing from impact sprinklers to sprinkler devices on drops results in water savings of 3-5 percent. If the entire canopy is wetted during irrigation, height of the sprinkler devices above the canopy will not be critical in further reducing water loss. In other words, closer is not necessarily better.

Figures 12.13a-c show how sprinkler device and placement can impact irrigation runoff. The dashed line in each figure shows the water application rate for that particular sprinkler device. The solid line is the infiltration rate curve for a silt loam soil. When the application rate exceeds the intake rate of the soil, water appears on the soil surface. If this application rate continues, runoff will occur.

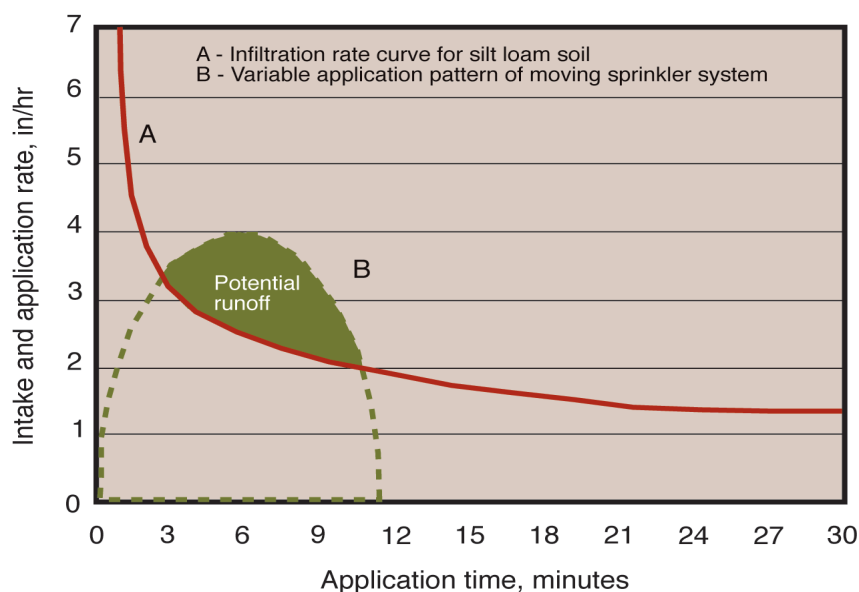


**Figure 12.13a**

Water application pattern for a sprinkler device located 6 feet above the ground with a 40-foot wetted diameter and an application time of 22 minutes. Water application should be less than or nearly equal to the intake rate of the soil to avoid potential runoff. In this case potential runoff will likely be seen as surface ponding, which is acceptable.

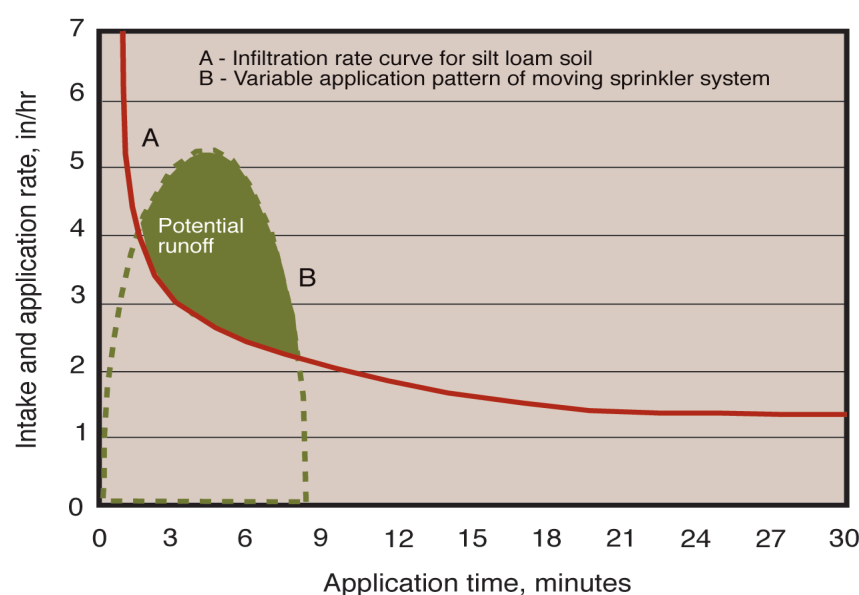
**Figure 12.13b**

Water application pattern for a sprinkler device located 6 feet above the ground with a 20-foot wetted diameter and an application time of 11 minutes. In this case selecting a sprinkler device that produces a smaller wetted diameter increases the amount of surface ponding and the potential for runoff.



**Figure 12.13c**

Water application pattern for the same sprinkler device as in Figure 12.13b (20-foot wetted diameter) except this one is located 3 feet above the ground. Placing a sprinkler device closer to the ground reduces the wetted diameter and further increases the potential for runoff. Application intensity is increased as the application time decreases to 8 minutes.



In Figure 12.13a, the sprinkler device is designed properly for the soil by using a sprinkler device that gives a 40-foot diameter of throw. In Figure 12.13b a spray device is selected which gives a 20-foot diameter of throw. As can be seen, the shaded area in the figure shows the amount of water being applied that has the potential to runoff. Finally, in Figure 12.13c, the spray device is lowered from a 6-foot height to a 3-foot height. This further reduced the diameter of throw and increased the potential for runoff. If runoff is observed from a sprinkler system, carefully consider the location of the sprinkler devices and the type of device being used.

Many irrigation systems are not designed to fully meet crop water needs. As the season progresses, if the soil profile has not been filled early enough in the growing season, crop water use will exceed application amount and water stress will occur. Remember that water stress early in the season restricts good root development rather than encouraging it, as was once thought. Start early enough in the growing season so when the peak water use period begins, the soil profile is nearly at field capacity. As water use exceeds irrigation application, water can be used from the soil profile as well as from the added water from the system to meet crop water demands.

## Water Management Impact on Disease

**S**eedling diseases in sugarbeet are encouraged by wet soil conditions during emergence and early plant growth. Water application is often necessary to establish a stand of sugarbeet; however, to avoid potential disease problems, irrigate before or soon after planting with adequate water to meet plant requirements for the first three weeks after emergence. Frequent, light applications of water, specifically with a center pivot, for germination and emergence provide ideal conditions for the development of damping off and root rot disease. (See *Chapter 11* for more details on these diseases.) If using surface irrigation, the soil profile is normally filled and does not require frequent irrigation. For a center pivot, if soil water is limiting, some water may need to be applied before planting. This is necessary because system capacity may limit the amount of water that can be applied in a short time and significant water application after planting can destroy soil surface structure.

Starting in late August and September, two diseases — *Cercospora* leaf spot and powdery mildew — can appear. Both diseases can be indirectly affected by irrigation. For *Cercospora* leaf spot the irrigation itself does not determine whether the disease will develop; however, if a spray program is started to control the spread of *Cercospora*, sprinkler operators should pay particular attention to the timing of fungicide applications. There is some evidence that the water applied to the leaves can wash some of the chemical control off and reduce effectiveness. Consider timing irrigations to complement the control program. Irrigate as much as possible before fungicide application, then allow several days without applying water. This is especially important if conditions are right for *Cercospora* leaf spot development.

Powdery mildew, like *Cercospora*, does not develop as a direct result of irrigation; however, sprinkler irrigation can wet leaves and wash organisms from the leaves. This may hinder, but not stop, the spread of the disease. To control powdery mildew, fungicide is applied to the leaves. Allow adequate time for the fungicide to dry on the leaves before irrigation. Once dry, the material should remain on the leaves even after irrigation. Since powdery mildew thrives in warm dry conditions, lighter more frequent sprinkler irrigations may contribute to lessening disease spread due to moist leaf conditions.

For both leaf spot and powdery mildew, furrow irrigators should continue to schedule irrigations based on crop water needs; however, some consideration must be given to irrigation timing if ground application of fungicide is necessary.



*The goal of irrigation management is to efficiently use water resources while maintaining water quality for others.*

## Scheduling Irrigation

A popular method for planning irrigation is checkbook scheduling. With this method, knowing how much water is held in the soil and the rooting depth defines how much water can be used or stored in the checkbook. From the checkbook account, crop water use is subtracted and precipitation and irrigations are added to determine a water balance. Remember to consider the efficiency of either precipitation or irrigation. For furrow irrigation it might be assumed that the entire soil profile is filled with each irrigation.

As an example, using *Table 12.1* assume an irrigation must be scheduled for sugarbeet grown under furrow irrigation on fine sandy loam soil in late July when roots are fully developed. To determine the beginning water balance, multiply a 3-foot rooting depth by the minimum balance of 0.9 inch. Total water held in the soil after an irrigation that fills the profile is 2.7 ( $3.0 \times 0.9$ ) inches. If crop water use for the last eight days averaged 0.25 inch per day or 2.0 inches, the water remaining in the soil is 0.7 ( $2.7 - 2.0$ ) inch. If crop water use is estimated to continue at the current rate of 0.25 inch per day, the water remaining in the soil would last for almost three days ( $0.7 / 0.25$ ).

For center pivot operators, it might be easier to replace the water that is used by the crop. For example, water use has totaled 2.0 inches during the past week and the irrigation system applied 1.75 inches at an estimated efficiency of 90 percent. Total water applied is 1.6 ( $1.75 \times 0.9$ ) inches. This means 0.4 inch ( $2.0 - 1.6$ ) of water was used from the soil profile but has not been replaced. Irrigation should therefore continue.

In many locations, it is suggested that room be left in the soil profile to store potential rainfall; however, in the Central High Plains, rainfall probability is low enough during the bulk of the growing season that this practice is not suggested. In most cases it only requires three days and there is storage available for 0.5 to 0.75 inch of water. Early or late in the growing season, this practice may provide a means to reduce irrigation.

*By John A. Smith*

A successful sugarbeet harvest provides the grower with the maximum **quantity** of sugarbeet root that was grown in the field and delivers to the processor the maximum **quality** of root to optimize processing efficiency. To achieve maximum productivity from the sugarbeet crop, the grower should address the following issues in preparation for and during harvest:

- Field preparation
- Crop maturity
- Timing of harvest
- Defoliation and scalping
- Digging and handling
- Root damage
- Field loss
- Soil damage for following crops
- Tare disposal
- Custom harvest
- Safety

Compromise will often be needed in consideration of all these harvest issues, but with proper attention and balance, harvest will provide the grower with maximum profit and the processor with a high quality raw material. Both quantity and quality are important harvest issues.

## Preparation of the Field in Anticipation of Harvest

Preparation for sugarbeet harvest begins with evenly spaced and uniformly sized roots, proper soil ridges centered with the crop row, adequate weed control, and good soil moisture. If not managed properly during the growing season, any one of these issues can make harvest difficult and increase harvest loss.

### Uniform Root Size

If seeds are uniformly spaced within the row and plants emerge at the same time, the resulting roots will be uniform in size. Uniformly sized roots protrude the same height above the soil surface. This uniform size and height allows easy and consistent defoliating and scalping. Seeds that are not uniformly spaced by the planter or fields with low emergence cause irregular sized roots and irregular crown height above the soil surface. When roots do not extend a uniform distance above the soil surface, the defoliator must be set for the tallest roots. If the defoliator is set too low, the large roots will be dislodged from the soil, or the top of the root will be removed by the flails, contributing to high field loss. When the defoliator is set correctly for the large, tall roots, then the smaller, shorter roots are not adequately defoliated and leaf material is left on the root. This contributes to high tare and potential for regrowth in the storage pile. Similarly, inconsistent diameter and height of roots makes good scalping nearly impossible. Small roots require a thin scalping cut while large diameter roots

*The need for a uniform root height above the soil surface is a compelling reason not to mix varieties in a planter.*

need a thicker cut. In addition, tall roots will hold the scalping knife too high to scalp a short root immediately behind the tall root. Good plant spacing, with uniformly sized roots, will reduce field loss and facilitate the defoliator to minimize tare and maximize scalping performance (*Figure 13.1*).

The need for a uniform height of root above the soil surface is a compelling reason to **not** mix varieties within the planter hopper. Often, different varieties, even within the same seed company, will have different crown diameter and height characteristics.

### **Soil Ridge**

Most growers form a small soil ridge around the base of the sugarbeet plant during the last cultivation or ditching operation. The harvester row finder often registers on the soil ridge instead of the top of the sugarbeet roots. If the soil ridge is not centered with the crop roots, the harvester will slice roots and cause high field loss. An examination of 45 Nebraska fields in a three-year study found that the major cause of excessive harvest loss was that the soil ridge had not been centered on the crop row. Although a good soil ridge will facilitate the harvester row finder, do not move excessive soil into the root crowns during cultivation or ditching operations or resulting *Rhizoctonia* root rot can be an even more serious problem. (See *Chapter 11, Disease Management*, for more information.)

### **Weed Control**

Weed control is important to eliminate competition with the sugarbeet plants for soil moisture and nutrients. Tall weeds and high weed populations also can create serious harvest problems for defoliating, lifting, and cleaning. If the defoliator is equipped with one drum of continuous steel flails, the weeds

**Figure 13.1**

Accurately spaced, uniformly sized sugarbeet roots will facilitate defoliating, scalping, and lifting.





will be cut off; however, the remaining weed root clumps and tops will create plugging and cleaning problems with the harvester. If the defoliator does not have steel flails on one drum, the large weeds or dense grass can cause wrapping of the defoliator, plugging of the harvester, and large amounts of weeds in the truck. Excessive weeds may cause the truck load to be rejected, based on contract agreements.

### Soil Moisture

Too much or too little soil moisture will create problems for sugarbeet harvest. If the soil is very dry, often the result may be broken tails, inability to maintain lifter wheel depth, and soil clods in the truck. If the soil is too wet, excessive slippage and sinking of the harvester tractor tires will often dislodge sugarbeet roots, increasing field loss. Wet soil will stick to the roots, increasing root tare and hauling costs. Wet soil also creates problems for trucks in the field, increasing the risk of damage to the trucks. Loaded trucks on wet soil will almost guarantee soil compaction that must be considered for the following crop.

If soil moisture is low as harvest approaches, consider an irrigation to improve harvest conditions. Other than waiting for the soil to dry, there are few management options for soil that is too wet for harvest. Harvest fields early that will become difficult to harvest if the soil becomes too wet. If harvesting in wet soil is necessary, consider using a sugarbeet cart with floatation tires pulled by a tractor with tracks or floatation tires to minimize soil compaction.

### Maturity of the Crop

A sugarbeet field that has not “matured” will not have satisfactory sugar content and will likely have excessive growth of plant tops. At harvest little can be done about maturity, unless weather conditions allow the crop to continue to grow, use up excessive soil nitrogen, and increase sugar content of the roots. Usually this is a management decision that must be made early in the season.

Excessive top growth will cause high horsepower and fuel input for defoliation. The large amount of shredded leaf material can cause tire slippage and will not allow the soil to dry if it is already too wet. About the only management options available are to use high flail rpm and low field speed for defoliating to maximize leaf shredding. Allowing the field to dry several hours between defoliating and digging also may help.

*Quantity and quality of sugarbeet are essential to a successful harvest. Both can be affected by defoliating and scalping.*

## When to Harvest

To determine when to harvest, consider the number of acres to harvest, capacity of harvest equipment and trucks, weather risk if harvest is delayed, and potential yield increase by delaying harvest if the crop is still growing. In most years, the crop is still growing and adding yield during the first and second week of October. A general rule is that if the crop is still actively growing during September and early October, sugar content will increase by 0.1 percent per day. A killing freeze can be anticipated in most years by the third week of October, stopping plant growth, making tops difficult to defoliate, and perhaps initiating regrowth and reducing sugar content. Most growers can not count on harvesting all their crop during the second week of October and will need to estimate the best time to start harvest. Rain, high or low temperature, or snow may delay planned harvest.

## Defoliation and Scalping

Both the quantity and quality of yield are influenced by the defoliating and scalping operation. Overly aggressive defoliating and scalping will reduce yield for the grower and will increase deterioration during storage because of the large, exposed root surface. If too much of the leaf or petiole is left on the root, root tare will be high and the root will tend to regrow in the storage pile. If the entire crown surface is left intact, impurities detrimental to processing will be high. The best defoliating and scalping compromise, for both grower and processor, is to remove all leaf and petiole material and to scalp only the very top of the root which contains most of the petiole scars. Review your contract for instructions on defoliating and scalping because this will determine the best process for each growing area (*Figure 13.2*).

Generally the best flail arrangement on a defoliator is solid steel flails on the front drum, with rubber flails over the rows on the second and third drums. The solid steel flails will cut up any weeds and will easily remove sugarbeet

**Figure 13.2**  
12-row defoliator equipped  
with scalpors.



leaves. The steel flails should be set to just clear the tallest roots. The front steel flails should have a relatively high rotational speed to pulverize weed and leaf material. If these flails touch the top of a very tall root, it will tend to cut the top off and not dislodge the root. The second and third drums with rubber flails should rotate much slower and contact the top of the roots down to at least the lowest leaf scar. Two drums of rubber flails will remove remaining leaf material without breaking the root if the drums rotate slowly, and if field speed is reduced. This combination of one front steel flail and two rubber flails works well for both unfrozen and frozen tops.

Forward field speed of the defoliator is important to both field loss and to root damage which contributes to higher storage loss. In a multi-field study in Minnesota, increasing field speed from 2 to 6 mph increased field loss, decreased yield and increased processing and storage losses. Flail configurations other than steel flails on the front drum and rubber flails on the rear drums did not compensate for increasing field speed. Results from this study clearly indicate that field speed for defoliating should be no more than 3 mph.

This same Minnesota study also found that scalping could not overcome inadequate defoliating. As with defoliating, field loss caused by the scalping operation increased as field speed increased from 2 to 6 mph. Again, to achieve good scalping, the defoliator field speed should be 3 mph or less. Higher field speeds caused the scalper unit to bounce and dislodge sugarbeet roots from the soil, increasing field loss.

Scalper knives must be sharp, and the depth of cut must match the root size and amount of crown to be removed. The down-force spring tension should be adequate to hold the scalper on the root tops but not so much that it dislodges roots.

## Digging and Handling

Carefully review your harvester operator's manual for adjustment and operation recommendations to maximize capacity while minimizing field loss and root damage. Check the row finder adjustments to keep the lifter wheels centered on the crop row to avoid sliced roots. If roots are large, consider wider spacing of the lifter wheels. Maintain adequate lifter wheel depth to get complete lifting. If the soil is relatively dry, try running the lifter wheels deeper and reduce field speed to prevent broken tails. If the soil is relatively moist, run the lifter wheels as shallow as possible to minimize soil taken into the machine while avoiding broken tails. If the machine is delivering too much soil into the truck, or if the roots contain too much soil tare, review your operator's manual for suggestions, such as making the grab rolls or squeeze chain elevators more aggressive for more cleaning. New paddle material on the paddles behind the lifter wheels will help loosen soil from the roots and transfer the roots to the grab roll bed. Consider adding lifter wheel spokes if too many small roots fall out the side of the wheels, or remove the spokes if the soil is very wet or too much soil is car-



ried to the grab roll bed. If soil tare is acceptable, but root damage is too high, make the grab rolls and squeeze chain elevators less aggressive. Frequently check the roots in the truck for too much soil or too much root damage. Also check the soil directly behind the lifter wheels for tails left in the soil (*Figure 13.3*).

**Figure 13.3**

As with this 6-row harvester, frequently check the roots in the truck for too much soil or too much root damage.



## Estimating Field Loss

The following guideline will provide a rough estimate of sugarbeet harvest loss in the field:

1. A sugarbeet root that is 3 inches in diameter at the large end will weigh approximately 1 pound. One root of this size, or root parts that add up to about this size, per 10 feet of row will average about 0.9 ton per acre for 30-inch row spacing and about 1.2 tons per acre for 22-inch row spacing.
2. Since most field loss is under the soil surface, use a shovel or dig by hand in the row area for sliced roots and broken tails, and between the rows for dislodged or broken roots, or large crown parts.
3. Check a 10-foot length of one row in at least five sections of the field to get a rough estimate of the average field loss.
4. If the harvest loss estimate is greater than 1 ton per acre, review equipment adjustments or operating practices to reduce field loss.

As much as possible avoid dropping roots from the harvester directly onto the bare floor of the truck. Load the trucks from one end or from the middle and allow roots to drop to the edge of the load already in place. Plastic liners help cushion the roots from the solid hard floor of the truck and help reduce build-up of wet soil.

## Root Damage

**T**ypical storage loss in conventional sugarbeet piles averages nearly one-half pound of sugar per ton of roots per day. Growers and processing companies generally share the cost of this storage loss. Part of that loss is controlled by weather conditions during storage, but some of the loss can be avoided by originally storing roots in good condition. Weeds and excessive soil on the roots restrict air flow in the piles and contribute to “hot spots”. Leaf tissue left on the root crowns encourages regrowth in the pile, decreasing sugar content and increasing pile temperature. Excessive scalping and slicing of the roots by the lifter wheels expose the root tissue to disease organisms that accelerate spoilage. Bruising of the root by overly aggressive grab rolls or elevators in the harvester, and by dropping the roots too far into the bottom of the truck also accelerates root deterioration in the storage piles. Carefully examine the roots periodically in the truck for breakage and bruising. Adjust the machine or operating practice to deliver roots that are in good physical condition for maximum storeability.

Roots are severely broken and bruised if the crop row is run over by tractors, trucks or harvest equipment. Arrange field ends so tractors and equipment can be pulled into and out of the field ends without running over the rows. Use a beet cart when opening up fields to avoid running over the rows when filling trucks.

Tractor or implement tires pushing against the side of roots in the row can break or bruise the roots. Use narrow tractor tires and maintain the tires centered between the rows to avoid root damage. Use rear tractor tires no wider than 12.4 inches for 22-inch row spacing and no wider than 16.9 inches for 30-inch row spacing.

## Field Loss

**T**otal field loss averaged 0.9 ton per acre and ranged from 0.2 ton per acre to 4.0 ton per acre in a Nebraska study of 45 grower fields during three years. Of this total field loss, an average of 75 percent was considered roots and root parts that should have been delivered to the processing facility. Five of the 45 fields had total field loss of 1.5 tons per acre or greater. Ninety percent of the field loss in these five fields was judged as roots and root parts that should have been delivered to the processing facility. Forty percent of the field loss in the forty fields with less than 1.5 tons per acre total loss, was contributed by large broken tails, 1 inch or greater at the large end. The remainder of the loss was distributed nearly equally among the categories of large whole roots, small whole roots, sliced roots, small tails, and miscellaneous root parts. Of the five fields with over 1.5 tons per acre total field loss, 35 percent was large tails, 30 percent was sliced roots, and the remainder was distributed among the other loss categories.

*Custom harvesting  
may be a cost  
effective option for  
many sugarbeet  
growers.*

The quantity of field loss in the 45 Nebraska grower sugarbeet fields, and the root or root part category for the loss, suggests producers focus on several aspects of harvest that contribute to highest field loss:

- Two-thirds of the 45 Nebraska fields inspected had field loss less than 1 ton per acre. This is a reasonable field loss target.
- Of the five growers who had excessive field loss over 1.5 tons per acre, all had a high percentage of loss attributed to sliced roots. These sliced roots were caused by the soil ridge not being centered on the crop row and the row finder following the soil ridge, or because the harvester pulled to one side on a hillside.
- The high percentage of large broken tails was judged to have been caused by lifter wheels set too shallow into the soil or excessive field speed.
- The factors of bad weather or soil conditions, night-time harvest, or pivot vs. furrow irrigation systems were not major causes of high field loss.
- Growers with high field loss had no idea they had high field loss, or that the loss was as high as it was. Most of the roots and root parts left in the field were covered with soil, or never dug, and thus were not seen.

## Soil Damage Affecting Following Crops

**S**ugarbeet harvest often occurs when soil moisture is relatively high. Tractors pulling defoliators and harvesters are often high horsepower and very heavy, and have narrow tires to fit between the rows. The pressure exerted against the soil by these tires and the harvester tires can create soil compaction, particularly in moist soil.

A far greater concern is soil compaction created by tires on loaded trucks. By the time the truck passes over the soil, the soil has been loosened by the harvester and is vulnerable to soil compaction. The pressure exerted against the soil by tires on loaded trucks can be as much as five times the pressure caused by tractor tires. A loaded truck will almost assuredly cause substantial soil damage in the form of

**Figure 13.4**  
Loaded trucks in the field,  
especially with wet soil,  
can create soil compaction  
and yield loss in the  
following crops.





soil compaction during sugarbeet harvest. A three- or four-row harvester will have many truck tracks through the field. About the only way to eliminate or minimize this soil compaction is to use a beet cart equipped with high floatation tires. In addition to minimizing soil damage, a beet cart can improve hauling efficiency by keeping trucks on roadways at the ends of fields. It also can reduce truck repairs caused by operating in rough and soft fields (*Figure 13.4*).

Once severe soil compaction develops it may take several field operations and several years to alleviate the condition. Soil ripping is usually not effective unless the soil is very dry. Moist soil will not shatter from shank to shank to help overcome the compaction; however, a deep ripping to loosen the soil at least 12-14 inches deep will allow repeated freezing and thawing action during the winter to penetrate deeper into the soil. If the soil is too wet in the fall to properly rip, a shallow ripping after harvest to provide surface roughness and improve freeze-thaw activity followed by deep moldboard plowing in the spring will provide maximum benefit.

## Tare Disposal

**D**o not return soil tare to any field where sugarbeet may be grown in the future. Tare contains soil that has been concentrated around the sugarbeet roots and is likely to contain a high concentration of soil pathogens harmful to sugarbeet production. Field tests have confirmed that sugarbeet pathogens and weed seeds can be spread to “clean” fields or concentrated in fields by returning tare to the field. Dispose of tare in non-crop areas.

## Custom Harvest

**S**ugarbeet harvest is the most expensive field operation per acre for ordinary field crops. The total cost of harvest including tractors, implements, labor, and trucks will usually exceed \$100/A. The harvest period is normally only two weeks long but can be extended to as long as five weeks if early harvest is included. It is difficult to effectively distribute the high initial cost and high maintenance cost of harvest equipment and trucks over this short period of time. If the trucks can be used for other crops or other purposes, the hauling cost for sugarbeet can be lowered.

Custom harvest and/or custom hauling is an alternative that some growers should consider. This can be especially attractive if the producer’s time and tractors can be used for other operations while the custom sugarbeet harvest is occurring. A second alternative is to provide labor, tractors, and implements to harvest the crop but use custom haulers to transport the crop from the field. The high capacity of six-row harvesters or even four-row harvesters will often be better used if a grower can hire an appropriate number of trucks and drivers to match the capacity of the harvester.

*Ensure safety is a priority during arduous hours of harvest.*

Another alternative for reducing harvest cost is for two or more growers to share labor and equipment and work together during harvest. This can accommodate pooling of larger scale, newer equipment to increase harvest efficiency. Within these arrangements, participating growers must discuss field scheduling, expectations for field loss, and other harvest issues to avoid potential disagreements.

## **Safety**

**S**ugarbeet harvest equipment is designed with chains, belts, top shafts, and other moving parts that, if unguarded, can cause serious injury and even death. The tractors, implements, and trucks are heavy and can crush individuals if they are run over or caught between or under the equipment. Trucks are large, heavy, and difficult to stop quickly, either in the field or on the highway. Work hours are often long, creating tired operators. Harvest can occur at night, or in the early morning or late evening when the sun is in the operator's eyes.

Sugarbeet harvest is potentially a very dangerous operation. Plan for safety to minimize accidents. Keep all machine guards in place. Stop all equipment and shut off engines when working on equipment. Use secure blocks when working under equipment. Do not get in front or behind equipment that is moving because the operator may not be able to see you. Use plenty of lights when harvesting at night. Stop frequently and rest to stay alert. Make safety a planned and integral part of harvest.

# Economics of Sugarbeet Production

**S**ugarbeet production presents many economic challenges from cost of production and production issues to concerns with government sugar policy. Sugarbeet are the highest value crop produced in the region, with corresponding high costs of production. This chapter will address these costs of production in detail. First, cost of production budgets will be developed to present the cost categories and value associated with both gravity and center pivot irrigated sugarbeet production. Second, an analysis of the different cost categories and the potential to reduce production costs through various management practices will be outlined. Finally, a method to evaluate the farm level economic impact of the adoption of a new production practice or technology will be discussed.

## Cost of Production Budgets

**S**ugarbeet are one of the highest cost crops grown in the region, costing more than \$600 per acre in most production systems. Cash costs regularly exceed \$400 per acre. Expensive specialized machinery, irrigation costs, and high input costs all contribute to the overall production costs.

The budgets used in this chapter were developed using interview data and machinery cost estimates developed by the University of Nebraska. Two enterprise budgets are presented in this chapter. First, the budget for gravity irrigated sugarbeet in the region is shown in *Table 14.1*. Second, a center pivot sprinkler irrigated budget is shown in *Table 14.2*. There are some differences in costs between these budgets, the most significant being the irrigation costs and the allocation of these costs. In addition, the gravity irrigated farms traditionally are smaller acreages resulting in higher fixed costs on a per acre basis.

The budgets are broken down into a variable cost section describing the individual operations and a fixed cost section describing the fixed cost on a cumulative basis. The variable costs for each operation include labor, fuel and lubrication, repairs, and materials and custom work required. Depreciation and interest, as estimated by the University of Nebraska, for the machinery used in these operations is found in the fixed cost section under the machinery heading. In addition, the fixed and variable costs for each operation are listed in *Table 14.3*. These operation costs are helpful when deciding whether to buy new machinery or use custom operations to substitute for machinery ownership. Additional operations may be added to these estimates, as well as extra operations subtracted from the budgets. One should also take care to review the inputs used in these estimates and make adjustments as necessary. Not all growers will use the same set of inputs at the same rates, so adjustments will be necessary in many cases.

Operating interest, general overhead, and operator management are assessed on the variable costs. Operating interest should reflect the amount of interest required to repay operating loans at a lending institution, or repay the grower for interest that could have been earned on money being used to grow a crop.



## Process for changing from a defined operation to a custom operation in the budget

### Step 1

Remove the variable costs of the plowing operation from the budget. Subtract \$6.35 from the total variable costs of \$372.81 leaving “your cost” of \$366.46.

Example line from gravity budget.

Variable Costs		Cost per acre					
Operation	Operation Acres/hour	Labor	Fuel & lube	Repairs	Materials & custom	Total	Your cost
Plow	2.89	3.15	1.29	1.91	0.00	6.35	0.00
<b>Total Variable Costs</b>		<b>77.45</b>	<b>9.64</b>	<b>19.60</b>	<b>217.17</b>	<b>\$372.81</b>	<b>366.46</b>

### Step 2

Determine the fixed costs for plowing in *Table 14.3* (depreciation = \$4.29 and interest = \$4.19.). Subtract these costs from the depreciation and interest lines on the budget and enter the new values in the “your cost” column. Total the fixed costs using the new values for depreciation and interest.

Fixed Costs							
Machinery	From <i>Table 14.3</i>						
Depreciation						58.68	54.39
Interest	@ 6.50%					50.53	46.34
<b>Total Fixed Costs</b>						<b>\$252.49</b>	<b>244.01</b>

### Step 3

Add in the additional line item for custom plowing as variable cost and adjust the total cost appropriately. For this example, custom plowing will cost \$14.00 per acre to be added into the variable cost section in the “your cost” column.

Variable Costs		Cost per acre					
Operation	Operation Acres/hour	Labor	Fuel & lube	Repairs	Materials & custom	Total	Your cost
Plow (Custom)							14.00
<b>Total Variable Costs</b>		As adjusted in step 1 ----->				<b>\$366.46</b>	<b>380.46</b>
<b>Total Fixed Costs</b>		As adjusted in step 2 ----->				<b>\$244.01</b>	
<b>Total of All Costs</b>						<b>\$625.30</b>	<b>\$624.47</b>

The general overhead is used to account for such items as farm liability insurance, irrigation supplies, shop supplies and other incidentals necessary to keep the farm operating efficiently. The management charge is what the operator should expect as a return for providing the expertise required to produce a quality sugarbeet crop.

With the high costs of production faced by sugarbeet producers, it is imperative that good production cost estimates be available for use as a planning tool. These budgets are a good place for growers to begin estimating their sugarbeet production costs and, when used in conjunction with their records and knowledge of individual production practices, can be helpful in making sound economic decisions. Use the column labeled “Your Cost” for those areas that may be inaccurate for a specific operation. These enterprise budgets should be used as a planning tool and are not expected to represent any specific actual farm. The user is expected to make the necessary adjustments to fit each farm unit.

The example on page 190 outlines the process for changing from one of the defined operations to a custom operator. The example shows how to insert “custom plowing” for “plowing” in the gravity irrigated budget.

The net result of substituting the custom plowing cost for the grower owned plowing operation is as follows:

- a) A net increase in variable costs by \$7.65, from \$372.81 to \$380.46. Variable costs were reduced by \$6.35 when the plowing operation was removed, and increased by \$14.00 when the custom operation was inserted.
- b) Fixed costs were reduced by \$8.48, from \$252.49 to \$244.01.
- c) Total costs of production were reduced by \$0.83, from \$625.30 to \$624.47.

This process may be used to change, remove or add any operation required to tailor the budget to an individual operation.

**Table 14.1**

Enterprise budget for gravity irrigated sugarbeet, High Plains Area, March 2000.

Projected revenue			Yield	Price		Total	Your
Crop			tons/acre	\$/ton		revenue	revenue
Sugarbeet			20.00	36.00		\$720.00	
Variable Costs		Cost per acre					
Operation	Operation acres/hour	Labor	Fuel & lube	Repairs	Materials & custom	Total	Your cost
Disc	10.63	0.83	0.50	0.60	0.00	1.93	
Spread fertilizer	16.04	0.53	0.16	0.20	36.90	37.79	
120-50-0 Fertilization rate							
Plow	2.89	3.15	1.29	1.91	0.00	6.35	
Roller harrow	6.55	1.35	0.79	0.63	0.00	2.77	
Roller harrow w/chem	6.55	1.35	0.79	0.63	18.80	21.57	
Roneet 2.5 pt/ac @ \$7.52/pt							
Plant	3.50	2.52	0.57	1.62	57.78	62.49	
Sugarbeet seed @ \$40.00/acre							
Counter 7 lb/ac @ \$2.54/lb							
Rotary hoe	13.44	0.60	0.18	0.27	0.00	1.05	
Cultivate	2.50	3.60	0.84	1.45	0.00	5.89	
Band spray	8.50	0.98	0.15	0.48	17.48	19.09	
Betamix 12 oz/ac @ \$103.00/gal							
Upbeet 0.17 oz/ac @ \$46.00/oz							
Cultivate	2.50	3.60	0.84	1.45	0.00	5.89	
Band spray	8.50	0.98	0.15	0.48	17.48	19.09	
Betamix 12 oz/ac @ \$103.00/gal							
Upbeet 0.17 oz/ac @ \$46.00/oz							
Ditch	5.29	1.73	0.80	0.79	0.00	3.32	
Hand weeding					20.00	20.00	
Irrigation labor	Season	50.00	0.00	0.00	0.00	50.00	
Spray cercospora	Custom	0.00	0.00	0.00	8.73	8.73	
Supertin 5 oz/ac @ \$2.34/lb							
Aerial spray @ \$8.00/acre							
Defoliate	5.60	1.65	0.47	1.24	0.00	3.36	
Lift	2.80	3.23	1.32	7.52	0.00	12.07	
Haul to pile	Custom	0.00	0.00	0.00	40.00	40.00	
Custom trucking @ \$2.00/ton							
Subsoil	6.58	1.35	0.79	0.33	0.00	2.47	
Crop insurance						15.00	
Operating interest						16.19	
General overhead						17.75	
Total Variable Costs		77.45	9.64	19.60	217.17	\$372.81	
Fixed Costs							
Machinery	From Table 14.3						
Depreciation						58.68	
Interest	@ 6.50%					50.53	
Irrigation							
Water taxes						25.00	
Land	Land investment \$1,200.00 per acre						
Interest	@ 5.0%					60.00	
Real estate taxes	@ 1.75%					21.00	
Operator management	10% of variable costs					37.28	
Total Fixed Costs						\$252.49	
Total of All Costs						\$625.30	



**Table 14.2**

Enterprise budget for center pivot irrigated sugarbeet, High Plains Area, March 2000.

Projected revenue		Yield	Price	Total	Your		
Crop		tons/acre	\$/ton	revenue	revenue		
Sugarbeets		20.00	36.00	\$720.00			
Variable Costs		Cost per acre					
Operation	Operation acres/hour	Labor	Fuel & lube	Repairs	Materials & custom	Total	Your cost
Disc	12.14	0.75	1.01	0.74	0.00	2.50	
Spread fertilizer	16.04	0.53	0.16	0.20	36.90	37.79	
120-50-0 Fertilization rate							
Plow	3.47	2.63	1.62	2.31	0.00	6.56	
Roller harrow	9.16	0.98	0.58	0.74	0.00	2.30	
Plant	3.50	2.14	0.76	0.94	90.21	94.05	
Sugarbeet seed @ \$40.00/acre							
Counter 7 lb/ac @ \$2.54/lb							
Nortron 24 oz/ac @ \$172.95/gal							
Rotary hoe	17.92	0.53	0.22	0.24	0.00	0.99	
Cultivate	7.05	1.28	0.64	0.38	0.00	2.30	
Band spray	9.16	0.98	0.15	0.48	17.48	19.09	
Betamix 12 oz/ac @ \$103.00/gal							
Upbeet 0.17 oz/ac @ \$46.00/oz							
Cultivate	7.05	1.28	0.64	0.38	0.00	2.30	
Band spray	9.16	0.98	0.15	0.48	17.48	19.09	
Betamix 12 oz/ac @ \$103.00/gal							
Upbeet 0.17 oz/ac @ \$46.00/oz							
Ditch	7.05	1.28	0.64	0.38	0.00	2.30	
Hand weeding					15.00	15.00	
Irrigation	Season	5.00	21.47	4.28	17.40	48.15	
Electric hookup charge \$17.40/acre							
Spray cercospora	Custom	0.00	0.00	0.00	8.73	8.73	
Supertin 5 oz/ac @ \$2.34/lb							
Aerial spray @ \$8.00/acre							
Defoliate	5.60	1.65	0.47	1.52	0.00	3.64	
Lift	2.80	3.23	1.64	7.29	0.00	12.16	
Haul to pile	Custom	0.00	0.00	0.00	60.00	60.00	
Custom trucking @ \$3.00/ton							
Subsoil	8.48	1.05	0.63	0.38	0.00	2.06	
Crop insurance						15.00	
Operating interest						16.95	
10% for 6 months							
General overhead						18.55	
5% of variable costs							
Total Variable Costs		24.29	30.78	20.74	263.20	\$389.51	
Fixed Costs							
Machinery	From Table 14.3						
Depreciation						37.50	
Interest						33.50	
Irrigation	Irrigation investment \$48.00 per acre						
Depreciation						4.56	
Interest	@ 6.25%					2.99	
Land	Land investment \$1,100.00 per acre						
Interest	@ 5.0%					55.00	
Real estate taxes	@ 1.75%					19.25	
Operator management	10% of variable costs					38.95	
Total Fixed Costs						\$191.75	
Total of All Costs						\$581.26	

**Table 14.3**

Operation list and associated costs for each operation by irrigation method.

	Variable costs (\$/acre)			Fixed costs (\$/acre)		
Operation	Labor	Fuel & lube	Repairs	Depreciation	Interest	Total
Gravity Irrigated						
Disc	0.83	0.50	0.60	1.76	1.41	5.10
Spread fertilizer	0.53	0.16	0.20	0.39	0.33	1.61
Plow	3.15	1.29	1.91	4.29	4.19	14.83
Roller harrow	1.35	0.79	0.63	3.85	3.14	9.76
Roller harrow w/chem	1.35	0.79	0.70	4.38	3.78	11.00
Plant	2.52	0.57	1.62	3.20	2.72	10.63
Rotary hoe	0.60	0.18	0.27	0.97	0.81	2.83
Cultivate	3.60	0.84	1.45	2.88	2.49	11.26
Band spray	0.98	0.15	0.48	0.82	0.67	3.10
Ditch	1.73	0.80	0.79	1.71	1.44	6.47
Defoliate	1.65	0.47	1.24	8.88	7.57	19.81
Lift	3.23	1.32	7.52	19.59	16.39	48.05
Subsoil	1.35	0.79	0.33	2.26	2.43	7.16
Pivot Irrigated						
Disc	0.75	1.01	0.74	1.90	1.51	5.91
Spread fertilizer	0.53	0.16	0.20	0.42	0.51	1.82
Plow	2.63	1.62	2.31	4.21	3.59	14.36
Roller harrow	0.98	0.58	0.74	2.24	1.80	6.34
Plant	2.14	0.76	0.94	3.83	3.66	11.33
Rotary hoe	0.53	0.22	0.24	0.92	0.94	2.85
Cultivate	1.28	0.64	0.38	1.37	1.01	4.60
Band spray	0.98	0.15	0.48	0.76	0.63	3.00
Ditch	1.28	0.64	0.38	1.52	1.36	5.18
Defoliate	1.65	0.47	1.52	3.34	4.17	11.15
Lift	3.23	1.64	7.29	13.08	10.82	36.06
Subsoil	1.05	0.63	0.38	1.78	1.86	5.70

## Evaluation of Production Cost Categories

Within the preceding production cost budgets, some areas would be difficult to change through improved management practices, while other areas may be significantly impacted by changing management strategies. Economies of scale can be captured within the sugarbeet production system in many of the cost areas. In addition, careful consideration of management practices such as crop scouting and soil testing will allow the sugarbeet producer to control the input costs per acre.

Agricultural producers can take advantage of economies of scale by spreading machinery, labor, and management resources over the optimum number of acres. Many of the resources required for sugarbeet production are specialized for this crop, requiring large capital or human resource investments to remain competitive. To reduce the per acre impact of these large investments, increased economies of scale may be accomplished by increasing the number of sugarbeet acres farmed. With the present rotational restrictions associated with sugarbeet,

an increase in sugarbeet acreage will require increasing the overall size of the operation or leasing land exclusively for sugarbeet production.

Another strategy for increasing economies of scale would be to share high cost resources among a cooperative group of farmers to spread the cost of those resources over an increased number of sugarbeet acres. Several smaller producers may be able to share the cost of planters, harvest equipment, trucks, and management expertise to decrease the overall fixed costs to each producer. Operators who enter into this type of arrangement will need to develop a level of trust and cooperation that allows for the benefits to be shared among all the participants.

Use of management tools such as crop scouting (either hired or done by the manager), soil testing, and pooling input purchases with other producers will allow the producer to control the high costs of inputs required for sugarbeet production. Crop scouting and soil testing will allow producers to apply pesticides and fertilizers as required instead of making input applications based on historic rates and tradition. With the high cost of inputs required for sugarbeet production, managing these costs is critical to the profitability of sugarbeet production.

Land, water, and labor costs are difficult to reduce within the present sugarbeet production system. This is a crop that requires high quality land with access to a consistent and large water supply. With these requirements, it is difficult to acquire land at low cost. High quality land is usually bid higher by producers interested in renting or owning land that has the productive capability to produce any area crop with a high yield potential. Water costs are either fixed, in the case of the gravity irrigated areas, or tied to the investment and energy costs required for the pumps and machinery required for center pivot irrigation. Sugarbeet is a labor intensive crop that has reduced the amount of labor required over the past several years by adopting plant-to-stand and chemical weed control practices. Growers who have not adopted these practices may realize cost savings with these technologies, but those who have already taken these steps will find limited labor cost savings. The budgets presented in *Tables 14.1* and *14.2* have incorporated plant-to-stand and chemical weed control technology.

## Partial Budgets for Decision Making

**A**s new technologies, advancements in equipment, and opportunities to have custom operators complete some of the tasks required for sugarbeet production become available, it is important that growers have the ability to do an economic evaluation. This section will explain how a partial budget may be used to evaluate new or alternative production practices. The partial budget shows how to determine the potential costs and benefits of adopting a new technology such as transgenic sugarbeet.

The partial budget is used to determine the change in net income based on the changes in costs and revenues from the production change being considered. There are four areas to consider when developing a partial budget:

- 1) **The additional costs associated with the change.** For the transgenic sugarbeet example, these costs will include the chemicals to be used, the technology fee associated with the seed, and any additional trips across the field with the sprayer.



- 2) **The reduced returns from any lost production or sales associated with the change.** The first two items will then be totaled to determine the potential income reducing components from the change.
- 3) **The additional returns due to the change.** In the case of transgenic sugarbeet, increased yield times the price received will determine the additional returns.
- 4) **Reduced costs of production.** In the transgenic sugarbeet system, the traditional chemical regime would be considered as reduced costs. The additional returns and reduced costs are then totaled to determine the income-increasing potential of the projected change. The example in *Table 14.4* shows how the partial budget can be used to assist in the decision making process.

### Transgenic Sugarbeet Example

University of Nebraska data on Roundup Ready® sugarbeet suggests that an additional two tons of yield may be realized from this technology. This data is used to illustrate how a partial budget (*Table 14.4*) may be used to develop economic projections for changes in the operation.

**Table 14.4**

Partial budgeting example for implication of transgenic sugarbeet production.

Proposed change to transgenic sugarbeet production		
<b>(1) Additional Costs:</b>		<b>\$/Acre</b>
Roundup Ultra RT	2 applications @ 1qt/acre @ \$41.25/gal	\$20.63
Broadcast spraying	2 applications @ \$1.61/acre	3.22
Technology Fee	Estimated at \$50.00 per acre	50.00
Hauling costs	2.0 T/acre increased yield @ \$2.00 per ton	4.00
<b>Total Additional Costs</b>		<b>\$77.85</b>
<b>(2) Reduced Returns:</b>		
None		\$0.00
<b>Total Reduced Returns</b>		<b>\$0.00</b>
<b>Total Additional Costs and Reduced Returns (A)</b>		<b>\$77.85</b>
<b>(3) Additional Returns:</b>		
Increased yield	2.0 T/acre at \$36.00 per ton	\$72.00
<b>Total Additional Returns</b>		<b>\$72.00</b>
<b>(4) Reduced Costs:</b>		
Betamix	2 applications @ 12 oz/acre @ \$103.00/gal	\$19.30
Upbeet	2 applications @ 0.25 oz/acre @ \$46.00/oz	15.64
Band spraying	2 applications @ \$1.61/acre	3.22
<b>Total Reduced Costs</b>		<b>\$38.16</b>
<b>Total Additional Returns and Reduced Costs (B)</b>		<b>\$110.16</b>
<b>Net Change in Income (B - A)</b>		<b>\$32.31</b>

# Scouting Calendar and Injury Diagnostic Guide

By Robert M. Harveson, Gary L. Hein, and Robert G. Wilson

**K**nowing when to scout and treat for pests and how to correctly identify the causes of plant injury are key elements of a successful crop production and pest management program. The following *Sugarbeet Scouting Calendar* and *Injury Diagnostic Guide* can be used as preliminary aids in countering insect, weed, and disease pressures and identifying potential causes of crop injury. More detailed information about pest scouting and treatment and recommended practices to avoid plant injury is provided in individual chapters.



**Figure 15.1**

Begin sampling for sugarbeet root maggot adults in early to mid May with peak fly activity in late May or early June.



**Figure 15.2**

Identify weeds early in the growing season so they can be effectively controlled.



**Figure 15.3**

Begin scouting fields for wilting plants in early June. Root symptoms of *Rhizoctonia* root rot consist of small circular lesions that coalesce to form larger areas of rotted tissues.

# Sugarbeet Scouting Calendar

indicates the presence of the pest  
 indicates period of greatest risk

Pest	Growing season							
	March	April	May	June	July	Aug	Sept	Oct
				Incidence				
Insects								
Seed/seedling feeding								
Carion beetle								
Army cutworm								
Pale-western cutworm								
Dark-sided cutworm								
Flea beetle larvae								
Flea beetle adult								
Symphylan								
Wireworm								
Foliage feeding								
Green peach aphid								
Bean aphid								
Beet leafhopper								
Blister beetle								
False chinch bug								
Grasshopper								
Leafminer								
Lygus bug								
Spider mite								
Webworm								
Zebra caterpillar, Woolly bear								
Root-feeding								
Sugarbeet root aphid								
Sugarbeet root maggot								
White grub								



Pest	Growing season							
	March	April	May	June	July	Aug	Sept	Oct
Incidence								
<b>Diseases</b>								
Aphanomyces root rot								
Cercospora leaf spot								
Cyst nematode								
Fusarium yellow								
Phoma leaf spot								
Powdery mildew								
Rhizomania								
Rhizoctonia root rot								
<b>Weeds</b>								
<b>Broadleaf</b>								
Canada thistle								
Cocklebur								
Jimson weed								
Kochia								
Lambsquarter								
Nightshade								
Pigweed								
Puncture vine								
Ragweed								
Redstem filaree								
Russian thistle								
Toothed spurge								
Smartweed								
Sunflower								
Velvetleaf								
Venice mallow								
Wild buckwheat								
<b>Grass</b>								
Barnyardgrass								
Foxtail								
Sandbur								
Quackgrass								
Wild oats								
Wild proso millet								

# Sugarbeet Injury Diagnostic Guide

Sugarbeet growth stage	Plant symptom	Probable cause
Emergence to two true leaves	Seeds cracked open, contents eaten Stand reduction	Mouse damage
Emergence to six true leaves		Aphanomyces Damping-off Moisture stress Freeze damage Army cutworms Grasshoppers Wind damage Herbicide injury Insecticide injury
	Cotyledons blackened, dried	Freeze damage Wind damage
	Black, thread-like hypocotyl with no wilting of cotyledons	Aphanomyces
	Plants dying with roots turning black	Flea beetle larval damage Sugarbeet root maggot
	Defoliation of leaves	Cutworms Grasshoppers Carrion beetle
	Shot-hole feeding on leaves	Flea beetle
	Leaves wilting, especially during heat of day	Sugarbeet root maggot Wireworm White grubs Moisture stress <i>Fusarium</i> <i>Aphanomyces</i> <i>Rhizoctonia</i> <i>Pythium</i> Rhizomania Cyst nematode
	Leaf spot/blotches	<i>Phoma</i> Leafminer
	Yellowing of leaves	Herbicide injury Nitrogen deficiency <i>Fusarium</i> <i>Aphanomyces</i> Rhizomania Cyst nematode
	Browning of leaf margins	Herbicide injury Insecticide injury Wind damage Frost damage
Two to six true leaves	Twisted stems and cupped leaves	Herbicide injury Insecticide injury

Sugarbeet growth stage	Plant symptom	Probable cause
Six to sixteen true leaves	Defoliation of leaves	Grasshoppers Blister beetles Webworms
	Leaves wilting	Sugarbeet root maggot <i>Fusarium</i> <i>Aphanomyces</i> Rhizomania Cyst nematode Moisture stress
	Tip of leaves yellowing	Lygus bug Herbicide injury
	Yellowing of leaves	<i>Fusarium</i> <i>Aphanomyces</i> Rhizomania Cyst nematode Herbicide injury
	Twisted stems and cupped leaves	Herbicide injury Curly top
	Leaf spot	<i>Phoma</i> <i>Cercospora</i>
Sixteen true leaves to maturity	White waxy material on roots and soil	Sugarbeet root aphid
	Leaves wilting, lower leaves dying, plants stunted	Moisture stress <i>Fusarium</i> <i>Aphanomyces</i> <i>Rhizoctonia</i> <i>Pythium</i> Rhizomania Sugarbeet root aphid Cyst nematode White grubs
	Defoliation of leaves	Grasshoppers Webworms Zebra caterpillar Woolly bears
	Yellowing of leaves	<i>Fusarium</i> <i>Aphanomyces</i> Powdery mildew Rhizomania Cyst nematode Nitrogen deficiency
	Leaf spot	<i>Cercospora</i> <i>Phoma</i>
	Twisted stems and cupped leaves	Herbicide injury





**active root zone** — The portion of the root zone with the greatest root concentration.

**acute** — Developing suddenly; or suddenly severe, as in describing disease symptoms.

**advance time** — Time required for a given stream of irrigation water to move from the upper end of a furrow to the lower end of the furrow.

**adventitious** — Arising not at its usual site; e.g., roots originating from stems, tubers, or leaves.

**agar** — Solidifying component of microbial culture media derived from certain marine algae.

**allelopathy** — Ability of one species to inhibit growth of same or other species through the excretion of toxic substances.

**anastomoses** (sing. anastomosis) — Interconnections between branches of the same or different hyphae (or other structures) to make a network; union or fusion of hyphae resulting in a sharing of their contents.

**aphid** — A small, sucking, homopterous insect living on plant juices and may be capable of transmitting viruses.

**ascospore** — A sexually produced spore formed within an ascus after the union of two nuclei.

**ascus** (pl. **asci**) — Sac-like cell in which ascospores (typically eight) are produced.

**asexual** — Lacking sex organs or produced in the absence of sexual recombination.

**available water** — The portion of water in the soil that can be readily absorbed by plant roots. It is the water held by the soil between field capacity and permanent wilting point.

**blight** — A disease characterized by rapid and extensive death of plant foliage.

**bulbil** — A small sclerotium-like structure made up of a small number of cells.

**canker** — Stem lesion with sharply delimited necrosis of the cortical tissue.

**canopy** — The uppermost spreading leaves of sugarbeet.

**carbamate insecticides** — Class of organic insecticides that act as nerve toxins in both insects and vertebrates by inhibiting cholinesterase; e.g. carbofuran (Furadan), carbaryl (Sevin), aldicarb (Temik).

**catenulate** — Formed in chains or in an end-to-end series.

**causal agent** — Anything (biotic or abiotic) capable of causing a disease.

**chlamydospore** — Thick-walled, asexual, resting spore formed by rounding up of a hyphal cell.

**chlorosis (adj. chlorotic)** — Abnormal plant color of light green or yellow due to incomplete formation or destruction of chlorophyll.

**chromosome** — A linear end-to-end arrangement of genes and other DNA which is the blueprint of an organism.

**cleistothecium (pl. cleistothecia)** — Closed, usually spherical, ascus-containing structure of powdery mildew fungi.

**CMS (genetic-cytoplasmic male sterility)** — This is an interaction between the genes in a plant that causes the plant to produce no pollen or pollen that is non-functional; making it functionally a female plant.

**coalesce** — Union of similar structures merging or growing together into a larger similar structure.

**competition** — The process by which plants vie for limited supplies of water, nutrients, and light.

**conidiophore** — A simple or branched fertile fungus hypha on which conidia are produced.

**conidium (pl. conidia)** — Asexual spore borne at the tip or side of a conidiophore.

**cortex (adj. cortical)** — Tissues between the epidermis and phloem in stems, tubers, and roots.

**cotyledon** — Seed leaf: primary embryonic leaf within the seed in which nutrient for the new plant is stored.

**cover crop** — A crop planted on a field to retard wind, water erosion, and add nutrients or organic matter to the soil.

**cultivar** — A cultivated variety.

**cyst** — A capsule around certain cells, as bacteria in a resting spore state; also the egg-laden carcass of a female nematode.

**cystosorus (pl. cystosori)** — A group of cysts or resting spores formed after division of a single protoplast.

**damping off** — Rapid, lethal decline of germinating seeds or seedlings before or after emergence.

**deep percolation** — Water which is applied in excess to that which can be held at field capacity, passes directly through the soil profile and does not contribute to plant growth.

**desiccate** — To dry out.

**diagnostic** — A distinguishing characteristic important for identification of disease or other condition.

**diameter of throw** — The distance from outside edge to outside edge of the water application pattern from a sprinkler.

**diploid** — A plant which has two copies of each chromosome — one copy from each parent. Human beings are diploid as are normal sugarbeet.



**dormancy** — Temporary suspension of biological activity in a seed.

**economic injury level** — The level of plant injury from a pest where the losses would equal the cost required to control the pest causing the injury; see economic threshold.

**economic threshold** — The pest population level at which control action needs to be taken to avoid reaching the economic injury level; see economic injury level.

**emergence** — Growth of the seedling shoot through the soil surface.

**encyst** — To become enclosed in a cyst, a capsule.

**evapotranspiration** — The combination of water loss from evaporation from the soil surface and transpiration from the leaves of the crop.

**exudate** — Usually an ooze or slime discharged from a diseased, injured, or healthy plant part.

**fallow** — Describing plant-free cultivated land kept free of a crop or weeds during the normal growing season.

**field capacity** — The amount of water remaining in a soil after it has been saturated and allowed to drain for approximately two to three days.

**flaccid** — Wilted, lacking in turgor.

**full canopy cover** — When the crop fully shades the surrounding ground.

**fumigant** — A vapor-active chemical used in the gaseous phase to kill or inhibit growth of microorganisms or other pests in soil.

**fungicide** — A substance that kills fungi; sometimes broadly used for substances that inhibit growth of fungi or spore germination.

**fungus (pl. fungi)** — Spore-producing eukaryotic organism lacking chlorophyll, often causing disease in higher plants.

**galls** — Localized enlargements (overgrowths) on plants.

**genetic** — Relating to heredity; describing heritable characteristics as influenced by germplasm.

**genetic-cytoplasmic male sterility (CMS)** — This is an interaction between the genes in a plant that causes the plant to produce no pollen or pollen that is non-functional, making it functionally a female plant.

**germinate** — To begin growth of a seed or spore.

**Gram stain** — A stain for differentiating bacterial types based on cell wall morphology.

**graminicide** — A herbicide designed to control grasses.

**herbicide resistance** — Property held by a group of plants within a species that develops tolerance to a herbicide.

**heterosis (hybrid vigor)** — The phenomenon that often occurs when two parents produce offspring that have certain qualities that are better than the same quality in either parent.

**host** — Plant that furnishes a medium suitable for development of a parasite.

**hyaline** — Colorless, transparent.

**hybrid seed** — Seed resulting from the cross of two parents that are genetically different from one another.

**hybrid vigor (heterosis)** — The phenomenon that often occurs when two parents produce offspring that have certain qualities that are better than the same quality in either parent.

**hypha (pl. hyphae)** — Tubular filament of a fungus.

**hypocotyl** — Portion of the stem below the cotyledons and above the root.

**immunity** — High resistance against a disease, exemption from infection.

**infection** — Entrance, establishment and subsequent multiplication of a micro-organism in a plant.

**infection court** — Site in or on host plant where infection can occur.

**infiltration rate** — The quantity of water that enters the soil surface over a given time.

**infiltration** — The penetration of water into the soil.

**inoculum** — The pathogen or its parts used for initiating disease.

**instar** — The period or stage between molts of an immature insect; e.g. first instar is the stage between egg hatch and the first molt.

**interference** — The combined influence of plant competition and allelopathy.

**interveinal** — Between veins.

**intracellular** — Within cells.

**inversion tillage** — Tillage that moves soil from the surface to lower depths within the soil profile.

**irrigation efficiency** — The ratio of the average depth of irrigation water beneficially used by the crop to the average depth of irrigation water applied.

**irrigation scheduling** — The process of applying the right amount of water for crop use at the right time.

**labeled germination** — The laboratory germination value appearing on seed container label. State seed laws govern the specific definition of this value and how it relates to the seed in the container.

**laboratory germination** — Usually referred to as the percentage of the seed sample that will produce a seedling under optimum laboratory germination conditions defined by seed industry standards.

**larva (or larvae pl.)** — An immature insect in an early stage of development that greatly differs in form from the adult; e.g. caterpillar, maggot, grub.

**lesion** — Distinct localized area of diseased tissue.

**mechanical injury** — Injury of a plant part by abrasion, mutilation, or wounding.

**meristem** — Plant tissue functioning principally in cell division.

**microsclerotia** — Very small sclerotia.

**minimum balance** — Minimum amount of water held in the soil before crop stress begins. This is approximately 50 percent of the available water.

**mm** — Millimeter,  $10^{-3}$ m, approximately 1/25 inch.

**mode of action** — Way in which a herbicide affects a plant at the cellular level.

**monogerm** — The monogerm sugarbeet seed is a seedball which is formed from one individual flower and produces only one seedling.

**mosaic** — Disease symptom usually of a virus; nonuniform coloration; a more or less distinct intermingling of normal, light green, or yellowish colored patches; a mottle.

**motile** — Exhibiting or capable of independent movement.

**mottle** — Disease symptom comprised of light and dark areas, an irregular pattern on a leaf.

**multigerm** — The multigerm sugarbeet seed is a seedball which is really two to eight individual seeds (from flowers located next to each other) that have grown together.

**muriform** — Having cells like bricks in a wall with both longitudinal and transverse septa.

**mycelium** — Mass of hyphae comprising the thallus or body of a fungus.

**necrosis (adj. necrotic)** — Death of plant cells or plant parts, usually accompanied by darkening or discoloration; a disease symptom.

**nematicide** — Chemical agent that kills nematodes.

**nematode** — Threadlike round worms of the order Nematoda, usually soil-borne, of which a number of microscopic size attack sugarbeet.

**node** — Joint in a stem, also the eye of tuber at which leaves and axillary buds are formed.

**nonselective herbicide** — A herbicide that is generally toxic to all plants.

**nonseptate** — Describing fungus filaments without cross walls.

**nymph** — An immature insect in an early stage of development that differs from the adult only in that it does not have wings and mature reproductive structures; e.g. immature grasshoppers.

**oospore** — Thick-walled, sexually derived resting spore of oomycetous fungi.

**organophosphate insecticides** — Class of organic insecticides that act in both insects and vertebrates as nerve toxins by inhibiting cholinesterase at the nerve junctions; e.g. malathion, chlorpyrifos (Lorsban), terbufos (Counter).

**parasite** — Organism that lives with, in, or on another organism (host), obtaining food from it; may benefit host in return, but more frequently causes disease in host.

**pathogen (adj. pathogenic)** — The causal agent of a disease.

**perfect stage** — The sexual stage in the life cycle of a fungus.

**perithecium (ph. Perithecia)** — The flask-shaped ascospore-producing fruiting body of Pyrenomycetous fungi.

**petiole** — Stalk-like portion of a leaf attached to the stem and supporting the lamina.

**pH** — Measurement of acidity or basicity: pH 7 being neutral, values below being acid, and those above being basic (alkaline).

**phloem** — Vascular tissue consisting usually of sieve tubes, companion cells, and parenchyma that conducts elaborated food materials.

**plant population** — The number of plants growing within a given area. Normally expressed in terms of number of plants per acre.

**plasmodium (pl. plasmodia)** — Naked mass of protoplasm without cell walls containing nuclei and cytoplasm, usually of a myxomycete.

**pore space** — Spaces in soil filled with water or air.

**postemergence** — Application of a treatment after the crop has emerged.

**primary inoculum** — Inoculum, usually from an overwintering source, that initiates rather than spreads or magnifies disease.

**primary symptom** — The symptom produced soon after infection, in contrast to a secondary symptom, which follows more complete invasion.

**priming** — A seed treatment that actually initiates the germination process and advances it to a predetermined stage. At this point germination can be safely stopped, and the seed can be further processed.

**pycnidium (pl. pycnidia)** — Asexual, globose or flask-shaped fruiting body of fungi producing conidia.

**pyrethroid insecticides** — Class of organic insecticides made as synthetic derivatives from pyrethrum, a product found in certain flowers; e.g. esfenvalerate (Asana).

**residual herbicide** — A herbicide that remains in the soil for several months or more.

**resistance (adj. resistant)** — Property of host that prevents or impedes infection or disease development.



**resting spore** — Temporarily dormant spore, usually thick-walled, and capable of surviving adverse environments.

**rhizosphere** — Micro environment in soil near to and influenced by plant roots.

**rogued** — Removal of a weed by hand pulling, hoeing, or cutting.

**saltation** — Bouncing of soil particles along the soil surface.

**saprophyte** — Nonpathogenic organism that obtains nourishment from the products of organic breakdown and decay.

**sclerotia** — Drought-resistant or heat-resistant form of fungus structure, usually with thick, hard cell walls permitting survival over adverse environments.

**secondary organism** — Organism that multiplies in already diseased tissue; not the primary pathogen.

**seed spacing** — The average distance between seeds within a row.

**senesce (n. senescence)** — To decline with maturity or age; often hastened by stress from environment or disease.

**septum (pl. septa)** — Cross wall in fungal hyphal strands.

**soil aggregates** — Collection of soil particles into a mass or body.

**soil evaporation loss** — Water that evaporates directly from the soil surface.

**soil moisture** — See soil water.

**soil water balance** — The status of the soil water content.

**soil water** — Water contained within or flowing through the soil profile.

**sporangiophore** — A specialized hypha bearing one or more sporangia.

**sporangium (pl. sporangia)** — A type of fungus structure producing asexual spores, often zoospores.

**spore** — Reproductive body of fungi and other lower plants, containing one or more cells; a bacterial cell modified to survive adverse environments.

**sporulating** — Producing and often liberating spores.

**sprinkler runoff** — The water that reaches the soil but does not infiltrate.

**steeping** — A seed treatment intended to leach naturally occurring germination inhibitors from the seed coat using mild chemical-water solutions.

**stroma (pl. stromata)** — A compact mycelial structure on or in which fructifications are usually formed.

**surge irrigation** — Surface irrigation method which automatically alternates flow between two irrigation sets.

**susceptible** — Lacking resistance; prone to infection.

**symptom** — The internal or external reactions or alterations of a host plant as a result of disease.

**systemic** — Spreading internally throughout the plant body.

**tetraploid** — This is a plant which has four copies of each chromosome — two copies from each parent. Sugarbeet can be chemically changed to become tetraploid.

**tolerance** — Capacity of a plant or crop to sustain disease or endure adverse environments without serious damage or injury.

**transgenic** — Establishment of resistance in a crop via genetic engineering.

**transpiration** — Water evaporation from the surface of plant leaves.

**triploid** — This is a plant which has three copies of each chromosome — two copies from one parent (usually the male or pollinator) and one copy from the other parent. Sugarbeet seed is triploid if one parent is diploid and the other parent in tetraploid.

**turgid** — Distension of cells or tissues due to water absorption.

**vector** — Agent that transmits inoculum and is capable of disseminating disease.

**vegetative** — Referring to somatic or asexual parts of the plant not involved in sexual reproduction.

**vigor tests** — Laboratory tests designed to evaluate the “vigor” of seeds or seedlings to emerge in a potential field situation. These tests often apply some form of stress to the seed during the germination and/or emergence period.

**virulent** — Having capacity for causing disease.

**viruliferous** — Virus carrying; can be an insect, nematode, or fungus.

**virus** — An infective particle consisting of protein and nucleic acid and capable of multiplying within plant or animal cells.

**water application efficiency** — The ratio of the average depth of irrigation water that infiltrates and is stored in the root zone to the average depth of water applied.

**wilting point** — The lowest point in the available soil water range. Plants have removed all available water from a soil and will wilt and not recover.

**xylem** — Complex woody tissue consisting of vessels, tracheids, fibers, and parenchyma that transports water and solutes and may serve also for mechanical support.

**zonate (n. zonation)** — Marked with stripes or lines more or less parallel to the edge of the lesion.

**zoosporangium** — A sporangium producing zoospores.

**zoospore** — Fungus spore with flagella capable of locomotion in water.

**µm** — Micron or micrometer,  $10^{-6}$ m, approximately 1/25,000 inch.